FACULTY OF TECHNOLOGY

Risk Management at an Early Stage of New Product Development

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ABSTRACT FOR THESIS

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Abstract

The world is moving at a very dynamic pace, and the unpredictability in the market environment is increasing rapidly. Hence the development of new products has become a challenge and has led to the failure of products in the market. To help overcome product failures, effective RM can play a vital role in the NPD process to reduce or manage risks proactively in the NPD process. Considering this aspect, studies also reveal that risks identified and managed at an ESNPD can help manage future risks efficiently down the NPD process. Furthermore, recent research concludes successful firms invest twice the money and time in the front-end activities before the development than unsuccessful firms. Hence this study seeks to investigate the current RM practices in PD industries and aims to provide necessary improvement proposals in this domain of research.

Risk and RM were defined based on various external frameworks like the ISO 31000, PMI & PRINCE2 to provide the basis of RM in this study. Furthermore, RM frameworks relevant to NPD were also reviewed in the literature review. To support the RM frameworks, extensive research was conducted in investigating two more research domain areas that are: (1) Potential risks identified at an ESNPD and (2) Standard RI techniques available for better risk identification at an ESNPD. Furthermore, a current state analysis was conducted in 5 PD case companies with 4 being SME's and one large scale enterprise to identify loopholes in the RM practices in the industry. In addition to this, venture capital investors were also interviewed to get a broader perspective on this study.

The empirical results indicated that none of the companies utilises RM process frameworks and RI techniques in a structured manner to support their management of risks. The thesis concludes by discussing how to better RM in PD companies by proposing an integrated RM process framework model. The process framework was designed by considering the loopholes found from the empirical research that best fits the characteristic of the PD companies. This research study provides valuable basic information on the RM process frameworks at an ESNPD and RI techniques that support the RM frameworks, which can also help in terms of extensive research for the future in this area of study.

Additional Information
Keywords: Risk management (RM), New product development (NPD), Risk identification (RI), Risk management frameworks, Early stage of new product development (ESNPD), Product development (PD).

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LIST OF ABBREVIATIONS

B2B: Business to Business
B2C: Business to Consumer
CEO: Chief Executive Officer
COO: Chief Operating Officer
CTO: Chief Technical Officer
DFE: Design for Environment
ESNPD: Early Stage of New Product Development
etc: et cetera
FMEA: Failure Mode Effect Analysis
FTA: Fault Tree Analysis
HBR: Harvard Business Review
i.e.: id est or in other words
ICM: Investigate, Communicate and Mitigate Process
IMA: Institute of Management Accountants
IP: Intellectual Property
ISO: International Standard Organisation
IT: Information Technology
NPD: New product development
PD: Product Development
PDP: Product Development Process
PMI: Project Management Institute
PRINCE: Projects in Controlled Environment
QFD: Quality Function Deployment
R&D: Research and Development
RBS: Root Breakdown Structure
RCA: Root Cause Analysis
RI: Risk Identification
RM: Risk Management
RQ: Research Question
SME: Small and Medium Scale Enterprise
SWOT: Strength, Weakness, Opportunity and Threat
VC: Venture Capital
VCI: Venture Capital Investor
VoC: Voice of Customer
WBS: Work Breakdown Structure

1 INTRODUCTION

1.1 The motivation of the research

"The management of new products is the management of risks; hence, your playbook has to be designed in a way to manage risks" (Cooper 2017). Considering the current dynamic environments product development (PD) companies operate in, companies encounter competitive pressure to deliver their products at the right time in the market with lower price and better quality to remain in a better edge than their competitors (Chalupnik *et al.*2009, Ulrich & Eppinger 2012). PD tends to become a highly complex process with a lot of uncertainties involved because of the integration of external and internal stakeholders' preferences to ensure an optimal set of product specifications (Sommer *et al.* 2008, Oehmen *et al.* 2010). Hence PD activities intrinsically involve in managing risks throughout the product development process (PDP). Various authors have designed their PDP in order to manage risks and believe having an effective product development process is essential for the survival and the success of the business since new products are the basis for competition (Brown & Eisenhardt 1995).

A good example is the "stage gate process" which is designed to reduce uncertainties and manage risks in the new product development (NPD) process (Oehmen *et al*. 2014, Cooper 2017). However, considering all the above aspects, the NPD processes written in the past have strictly relied on a "standard list of action" or standard set of procedures for each stage in the NPD process and thus resulting in a standard set of deliverables. Instead, it is suggested for the team to map out its own action plan, which can specify for a particular project as every project is unique. The involvement of risk management (RM) is suggested to be involved in the NPD process to make the entire PDP more adaptable and flexible (Cooper 2017).

Studies reveal the early stage of new product development (ESNPD), that is the stage prior to the actual development of the product can make the difference between winning and losing of the product. The *"game is won or lost in the first five plays."* (Cooper 2013, Cooper 2017, Cooper 2019, Edgett 2011). This makes ESNPD or pre-development homework essential for the success of a product. Recent research concludes that successful firms invest twice as much money and time in the front-end activities than unsuccessful firms (Cooper 2019). It is vital to consider RM in the PDP to minimise the

impact on the performance of the project, and a successful RM approach can help in the probability of success in a project (Park 2010, Royer 2000). During the PDP, each activity is vulnerable to various types of risks that can occur during the development process. Hence not considering risks throughout the PDP does not make sense (S. Škec *et al*. 2014, Mu *et al*. 2009).

The main activities of RM involve identification of risks, analysis and evaluation of those risks and finally controlling those risks to avoid or mitigate potential negative impacts on the PD project (Meyer *et al*. 2002). However, when considering the risk assessment process, it is risk identification (RI) that plays an important role as any failure in the RI process can make the entire process inefficient (Rostami 2016). Furthermore, recently published articles emphasise on boiling down the risk categories in PD into 3 to 4 risk categories, id est (i.e.)., technology, organisational, market and commercialisation risks, which can impact the performance of NPD (Salavati *et al.* 2016, Mu *et al*. 2009, Keizer *et al*. 2005). All the above factors show the need for the involvement of RM at an ESNPD.

They have been various external frameworks developed on how to manage risks for any industry such as the ISO 31000 (ISO 31000:2009), project management institute (PMI 2013), and projects in controlled environment (PRINCE2) (Murray 2009). On the other side there is limited literature available on RM as an integrated part of the NPD process, especially at an ESNPD. This thesis aims to fill the above-addressed gap by analysing the current state RM practices in SME's and large-scale companies to further provide appropriate recommendations on the integration of RM at an ESNPD.

1.2 Research scope and objectives

Addressing the research gap from section 1.1, the main aim of this thesis research is to analyse on what are the current RM practices at the front-end of the PDP in PD case companies and further provide necessary recommendations. Through this analysis, the thesis aims to provide an enhancement in the current literature review findings with the identification of loopholes in the RM practices in PD companies. Further, the empirical research, in combination with the literature review findings supplements in providing appropriate recommendations on the integration of RM at an ESNPD. This thesis can further help take the next leap of research in this area to conduct RM more intuitively in different PD type companies. From this research gap and scope context, the overall

research objective of this thesis is formulated to address the following three research questions shown below.

RQ1: What are the RM process frameworks and RI techniques utilised to manage identified risks at an early stage of new product development?

RQ2: How are RM process frameworks and RI techniques currently utilised at an early stage of new product development in PD case companies?

RQ3: How can the current RM practices in the PD industry be improved for better adaptability and flexibility at an ESNPD?

1.3 Logical structure of the research

Addressing the scope, objectives and motivation for this research in the previous sections 1.1 and 1.2, figure 1 lays out the research logic of the thesis. The research logic of this thesis is divided into 4 phases: The literature review, current state analysis, recommended RM process framework and the conclusions phase. The literature review research focusses on mainly four research areas. Chapter 2.1 gives an introduction to the various NPD processes from different authors. Furthermore, the NPD process is explained by narrowing it down to the ESNPD by understanding the business case criteria before the product enters into the actual development stage. The literature of chapter 2.2 and chapter 2.3 briefly introduces the concept of risk and RM with reference to the standard RM external frameworks like the ISO 31000, PMI & PRINCE2 with ISO 31000 being more emphasised on.

Chapter 2.4 investigates on the various RI techniques utilised to identify risks in projects and also PD projects. Subchapters 2.1,2.2,2.3 and 2.4 act as the necessary foundation of the literature to integrate RM into the ESNPD in chapter 2.5. As per the research aim of this thesis, chapter 2.5 of the literature review introduces RM at an ESNPD by aligning the objectives of this thesis. This extends chapter 2.5 in researching the various risks identified from various authors at an ESNPD by synthesising each risk under each category of risk in the NPD process to finally answer RQ1. Furthermore, this chapter

compares and discusses the existing RM frameworks that are relevant as an intrinsic part of the product development process based on past available literature.

The literature review provides a foundation for the empirical analysis through which, a semi-structured questionnaire and a short comprehensive questionnaire on RM at an ESNPD is prepared to empirically investigate on the current state RM practices in multiple PD case companies. Four small and medium scale enterprise's (SME's), one large scale company and one venture capital investor (VCI) were empirically investigated to answer RQ2 in chapter 3. The semi-structured questionnaire is divided into four main subsets: ESNPD process in case companies, RM frameworks in the NPD process, RI techniques and potential risks identified at an ESNPD. The short questionnaire supported the semi-structured interview sessions by answering on the RI techniques and potential risks identified at an ESNPD. The reason for selecting one large scale and 4 SME's with one VCI was to get a broader view in terms of results. Further, the study discusses the results of the literature and empirical findings; this combined result support in recommending an integrated RM process framework to answer RQ3 in chapter 4. Finally, chapter 5 gives the conclusions in light to the research questions of this thesis with further mentioning the limitations and future outlook of this research study.

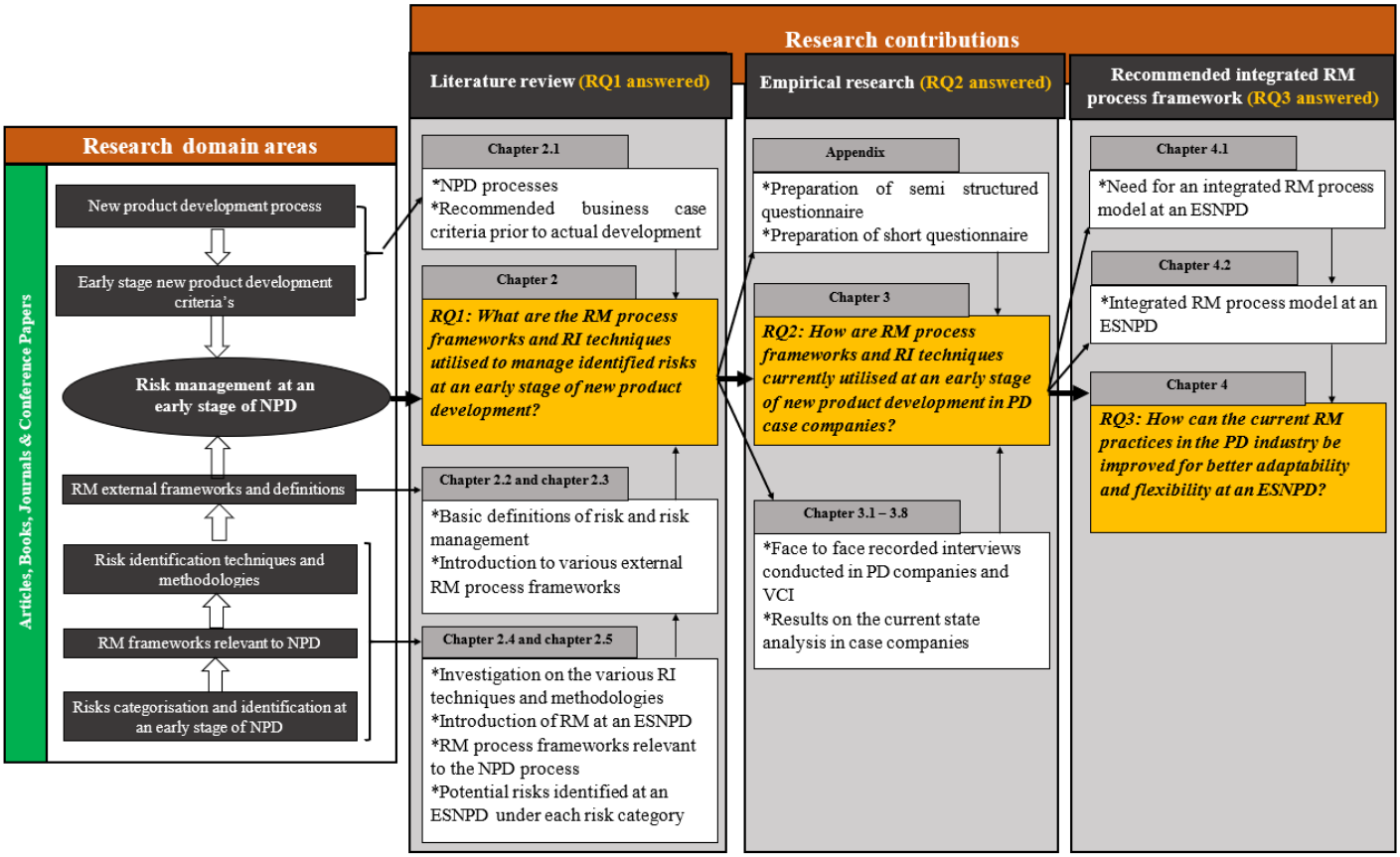

Figure 1. The logical structure of the thesis

2 LITERATURE REVIEW

The following literature review outlines the needed literature concepts that are pertinent to this thesis study. To conduct further research on risk management at an ESNPD, two main fields were taken into considerations that are new product development (NPD) and risk management (RM). Considering the two main fields taken into account in this thesis, the first research question is aimed to be answered by analysing the past available literature in various domain areas of RM in relation to NPD with the aim to gain valuable findings in integrating RM at an ESNPD. The literature review is used as a pillar in the investigation of the empirical research and the contributions of the results of this thesis.

2.1 New product development process

It is essential to define what is a product, the NPD processes, criteria prior to actual development, i.e., criteria at an ESNPD and required crucial aspects of product development to strengthen the ESNPD in this thesis. This section gives a detailed explanation of the topics mentioned above.

2.1.1 New product development processes

There are several definitions of what a product is, according to many authors. A product is *"Something sold by the enterprise to its customers"* (Ulrich & Eppinger 2012). On the other hand, Cooper (2017) defines a product broadly as *"Anything referred to as an external marketplace for sale, use, or consumption and this includes physical products as well as services, and the combinations of services and products"* (Cooper 2017). Ulrich and Eppinger (2012) give the most explicit definition on PD as "*a set of activities that begin with market opportunity and finally end with the production, sale and delivery of the product to the customers"* (Ulrich & Eppinger 2012). PDP is a methodology and a procedure followed by companies to design new products and introduce them to the market (Unger & Eppinger 2011). Two product development processes by Ulrich and Eppinger (2012) and Cooper (1990) are explained in this chapter in detail by utilising figure 2. According to Ulrich and Eppinger (2012), the general PDP comprises of six phases in which the planning and concept development is very relevant to this thesis, which comes under the ESNPD. The six phases are shown as follows (Ulrich & Eppinger 2012):

- *Planning*: This phase is known as the zeroth phase in the NPD process as it is before the project approval and the launch of the actual product. The activities involved in this phase mainly involve identifying the market opportunity, the definition of the market segments, new technology assessments and also the identification of production constraints et cetera (etc.)
- *Concept development*: In the concept development phase, identification of the customer needs is an integral part of the concept development process. This need identification then helps set specifications, generate a variety of products, select and test the product for further downstream development.

  During the concept development process, the team performs an economic analysis to create an economic model of the product to ensure the continuous development of the product to handle development and manufacturing costs of the product. "Benchmarking of competitive products" is also performed in this stage continuously to position the new product and support the front-end activities. Also, in order to determine the feasibility of the product, modelling and prototyping of the product take place in the concept development stage, which can help in re-designing the product for robust performance.
- *System level design:* In this phase, the definition of the product architecture, the sub-systems of the product and components with the preliminary design of the critical elements is conducted. The main output of this phase is the products geometric layout, functional product specification for each sub-system and initial process flow diagrams for the final assembly process of the product.
- *Detailed design:* In the detailed design phase, the complete specifications of the product are understood, and the parts of the products that need to be purchased from the supplier are planned. All these outputs to the controlled documentation for the product. Three critical issues that are finalized in this stage are materials selection, production cost, and robust performance.
- *Testing and refinement:* In this phase initially, alpha prototypes are built and tested with product intended parts, which need not be the actual parts fabricated from the production process. Later on, beta prototypes are made from the suppliers' parts, maybe by not utilising the actual final assembly process. These prototypes help finally in identifying necessary engineering related changes in the product.
- *Production ramp-up:* In this phase, the actual product is produced from the intended production system process. In this phase, the workforce is trained, and the left-out problems in the production process are resolved. The products

produced during this phase are provided to the preferred customers and evaluated for flaws. The transition from ramp-up to production is a gradual process as well, and during this transition phase is when the product is launched and is available for distribution. The post review stage occurs soon after the launch of the product.

Another popular tool for managing new products is the stage-gate system. The stage gate process helps identify that product innovation is a process, where process management methodologies are applied, and it works as a process. The processes are sub-divided into five stages, and between each stage, there is a checkpoint or a gate, where a criterion is set for the product to move to the next stage. It is very similar to the 6 phases of (Ulrich & Eppinger 2012). The five stages in the stage gate process are explained as follows (Cooper 1990):

- *Idea screen:* This screen, as the name suggests, begins with the idea generation of the product. After this stage, it is followed by an *"idea screen gate"* which is more of an easy go-decision gate. Strategic alignment of the project, feasibility of the project, the scale of opportunity from this project, market attractiveness is some of the criteria's considered for decision in this gate. This gate is subjected to a *"must meet"* or *"should meet"* criteria.
- *Preliminary assessment:* This stage mainly involves two preliminary assessments that are the market and technical assessments. The primary purpose of the market assessment is to understand the scope for the market potential, the product attributes, the size of the market, and how willing is the market to accept their product. The purpose of preliminary technical assessment in this stage is to assess the manufacturing and development feasibility, first technical appraisal of the project and identification of technical risks.

  The preliminary assessment is followed by the second gate, which is similar to the first initial screening gate with the "must meet" or "should meet" criteria with much more information available in hand. At this stage, minor financial calculations are assessed like, for example, payback period. If the decision is "go" at this gate, then it is moved to the next crucial gate because the project moves into a larger expenditure stage.
- *Detailed investigation (Building a Business case):* This stage is the final stage before the actual development of the product and can be called as the last stage of

the ESNPD. The detailed investigation stage is a critical stage as in this stage, the product is said to be clearly defined. Again, this stage involves two detailed assessments that are the technical and marketing assessment in the market assessment detailed market study, market research, the voice of customer (VoC) research. Similarly, in the technical assessment the in-depth tech-appraisal, intellectual property (IP) issues are resolved, supplier sourcing assessment and also the customers need or wish lists are translated into technological and economical solutions at this stage. Finally, this stage concludes with a detailed financial analysis as an input to gate three before the final investment decision to go to full-scale development is decided. The project is subjected to a "must meet" and "should meet" criteria again at gate 3. Once this gate is passed, financial commitment gets very important. The phase after gate three is called "go to a heavy spend" phase. Criteria's involved in gate 3 are shown in table 1.

- *Development:* As the name of this stage suggests, it involves the development of the product and simultaneously of detailed testing, marketing and operational plans. Also, financial analysis is conducted during the process of development for continuous updating. Other issues like IP, copyright, patent issues are resolved. After this stage, the "post-development gate" exists to check on the progress of the product in terms of quality and the attractiveness of the product. Financial analysis is also reviewed well to ensure more precise data available at this gate. Also, to immediately implement the testing and validation in the next stage, the plans of the next stage are approved in the development gate itself.
- *Testing and validation:* In this stage, the entire viability of the product is tested. The activities that take place in this stage are checks on products quality and performance, checking functionality of the product under use conditions, production process testing and debugging in order to have updated and explicit production costs and rates, trial testing of the product in the market in order to understand customer reaction, determine expected market share and revenue and finally more accurate financial analysis to provide a clear picture of the revenue and cost data.

After this stage, there is the final gate, which is the "pre-commercialisation" gate, and this is the final stage at which the product can still be killed. In this gate, quality of activities is reviewed from the validation stage, and the financial analysis is discussed again and play a critical role in decision making at this stage.

In the end, the marketing and operational plans are checked and approved for implementation in the commercialisation stage.

- *Commercialisation*: Commercialisation is the final stage in the stage-gate system and mainly involves the plan on the launching of the product in terms of marketing and operational plans.
- *Post review stage*: At this stage, a post-audit on the critical assessment of the project is conducted with the latest data of the project available in hand. The strengths, weaknesses and learnings are assessed and documented for future projects on what can be improved in the next upcoming projects.

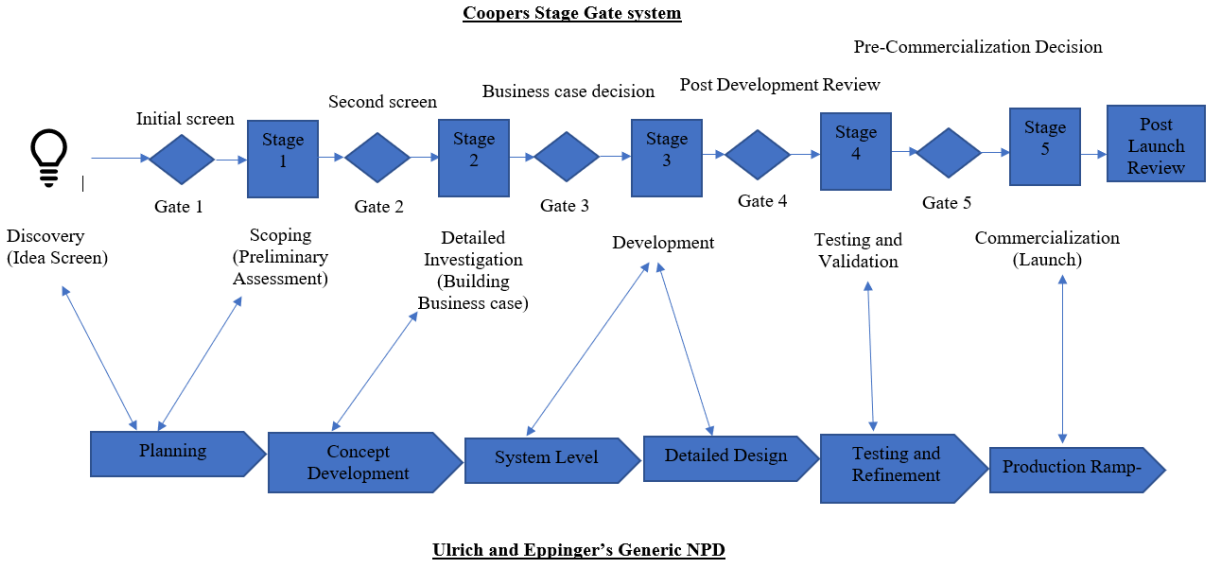

Figure 2. NPD processes (Modified from Ulrich & Eppinger 2012, Cooper 1990)

Many firms like Johnson & Johnson, P&G, Emerson Electric, Information telecom and technology industries utilise scorecards to make better *"go/no-go"* decisions at an ESNPD. Gatekeepers challenge the project team with their questions and finally collect answers individually and input their scores in the scorecards. Finally, these results are shown, and the gatekeepers further discuss and come up with a decision (Cooper 2008). The traditional stage gate process did face a lot of critics on being very rigid, linear, and is too planned to handle innovative and dynamic projects. To solve this issue, Cooper (2014) came up with different scalable product development models based on the risk level of the projects. These scalable models basically overlap stages based on the type of development project to reduce unwanted activities (Cooper 2014). Also, according to a short survey, 75% of the top performing business firms have developed context based

scalable stage gates to handle less risky, better defined and less complicated projects (Cooper & Edgett 2012).

2.1.2 Recommended business case procedure at stage 2

Since my thesis mainly focusses on the ESNPD, gate 3 is more emphasised and can be considered as the most important gate in the front end process. The criteria at gate 3 may vary depending on the type of project. The standard criteria in gate 3 in the stage gate process is shown in table 1 (Cooper 2008).

A recent study on new product failures shows that 73% of products fail due to lack of market research, 54% because the product launch or commercialisation of the product was poorly conducted, and 49% of product failures happened in product deficiency because of weak product testing. Further studied analysis suggests that the front-end of the innovation process is where most of the weakness occurs (Cooper 2019, APQC 2003, Cooper 2017). The business case procedure can be used as a foundation in any organisation to conduct systematic improved business case analysis before the actual development of the product (Kinnunen *et al*. 2011). The decision criteria of the stage-gate model provide an effective interface for incorporating project risk concepts (Bowers 2014). These set procedures and criteria from the past research can very well work as a foundation for RM at an ESNPD.

Various authors have researched on the criteria's to be considered in the business case procedure in stage 2. Considering the common criteria dimensions between authors like Hart *et al.* (2003), Carbonell-Foulquie *et al*. (2004) and Cooper (2008) it can be found that *"market-related criteria's, financial criteria's, technical feasibility criteria and strategic fit criteria"* dimensions were found to be common (Hart *et al.* 2003, Carbonell-Foulquie *et al*. 2004, Cooper 2008). Kinnunen *et al*. (2011) from his research on various authors comprehensively divided the criteria for gate 3 into three main categories that are "*market-related criteria, technical criteria and financial performance criteria"* and also shows the business case procedure on how to build a business case in stage 2 as shown in figure 3 (Kinnunen *et al*. 2011).

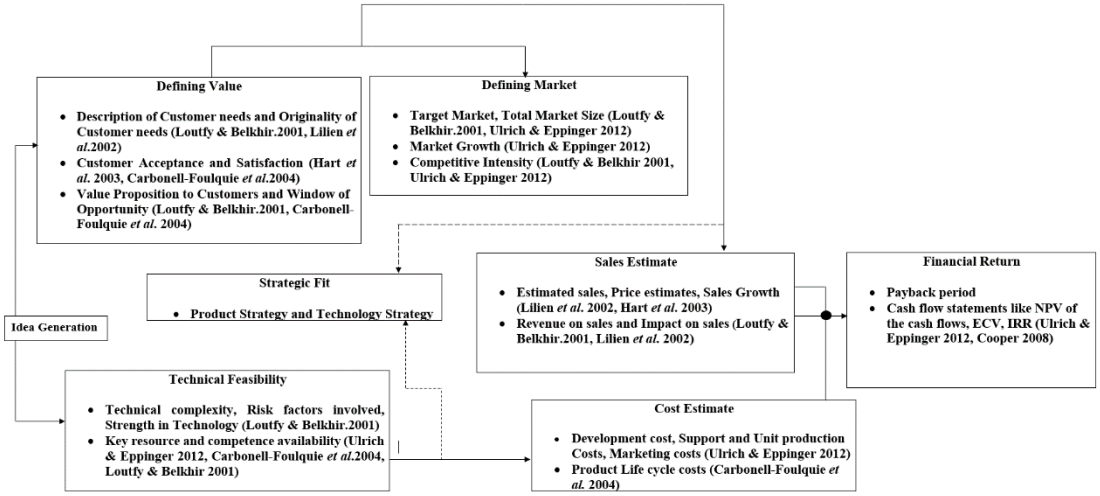

Figure 3. Business case procedure at stage 2 (Modified from Kinnunen *et al*. 2011)

Table 1. Typical gate 3 criteria and scorecard (Cooper 2008)

Strategic fit and importance • Alignment of the project with business strategy and its importance to the strategy • Impact on the business
Product and competitive advantage • The uniqueness of the product to its customers • The product provides value to the customers (Value proposition) • Positive customer feedback from product concept test results
Market attractiveness • Market size and its growth with good future potential in the market • Margins earned by players present in the market • Competitive analysis of the market
Core competencies leverage • Technical • Production • Marketing • Distribution
Technical feasibility • Size of the technical gap • Complexity in the technology • The familiarity with the technology to the company • Proof of concept
Financial reward vs risks • Size of the financial opportunity • Financial return calculations (Net present value, expected commercial value, internal rate of return, productivity index) • The certainty of financial estimates • Level of risks involved and the ability to address risks

2.2 General introduction to risk management

2.2.1 Risk definition

There are various definitions of risks by multiple authors and external organisations. ISO 31000 defines risks as *"Risks – The effect of uncertainty on objectives"* (ISO Guide 73:2009, Definition 1.1). Other external framework organisations like the project management institute (PMI) define risks as "*An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality"* (PMI 2013). Projects in a controlled environment (PRINCE2) gives a similar definition on risks which states it is "*A risk is an uncertain event which, should it occur, will have an effect on the achievement of objectives"* (Murray 2009). All these definitions are similar in terms of the "impact on the objectives". However, the definitions, as mentioned above, also consider risk as an opportunity than a threat.

Authors define risks as *"uncertain factor"*, which is either positive or negative. As risks have always been an inevitable event that occurs in most projects and managers always find it a challenge in handling risks when they occur suddenly (Meyer *et al*.2002). In the context of PD, several authors define risk in terms of the technical and design reliability point of view of the product (Browning *et al*. 2002, Levin & Kalal 2003). The dimensions of risks in the context of PD as per Unger and Eppinger (2009) are technical, market, schedule or budget risks (Unger & Eppinger 2009). Risks in an organisation can be understood in 2 terms that are "stake" and "uncertainty". In terms of the stake, the stake can be financial gain or loss, improvement or deterioration in a strategic position, a threat to a company's existence, or an increase or decrease in its sense of security. On the other hand, uncertainty varies with regard to the time and current scenario (Clarke & Varma 1999, Meyer *et al*. 2002).

2.2.2 Defining risk management

ISO 31000 defines RM as *"coordinated activities to direct and control an organisation with regard to risk"* (ISO Guide 73:2009, definition 2.1). This thesis follows the ISO 31000 as a guiding standard. Another strong definition of RM is from the PMI which

defines RM as *"A process of conducting RM planning, identification, analysis, response planning, and controlling risk on a project"* (PMI 2013). PRINCE2 also defines RM similar to PMI (2013) as *"RM refers to the systematic application of principles, approach and processes to the tasks of identifying and assessing risks and then planning and implementing risk responses"* (Murray *et al*. 2009). According to a Harvard business review (HBR) to have an effective RM system, the organisation should be able to identify the qualitative distinctions among the type of risks that the organisation faces (Kaplan & Mikes 2012). This makes comprehensive RI as a critical step in the entire risk assessment procedure (ISO 31000:2009). The taxonomy of risks as per the HBR is divided into three categories preventable risks, strategic risks & external risks. The three risk categories can be dangerous to the company's strategic goals. Preventable risks arise from within the organisation, and these risks can be controlled. The second category is the strategic risks which are different from preventable risks because they are not as welcoming as avoidable risks. To manage strategic risks the organisation has to have a good RM system to reduce the impact of these assumed risks and make sure these risks are handled well in the case occurred in the further course of action. The third category is the external risks which are entirely out of the organisation's control (Kaplan & Mikes 2012).

2.3 Risk management external frameworks

The ISO 31000 is considered as the guiding framework in this thesis. Hence this chapter begins with the understanding of three fundamental concepts of ISO 31000: the principle, the framework and the process of risk management (RM). The *"RM principles"* of ISO 31000 explains the need and the important features of RM in an organisation. The *"RM framework"* gives a good understanding on the broad activities like "mandate and commitment," "implementation of RM," and "monitoring and review" in different levels of the organisation which can help in the development of RM processes. Finally, the *"RM process",* which is in short, the implementation of the activities like "establishing context, RI, risk analysis, and risk mitigation (ISO 31000:2009, IRM 2018). Furthermore, other external frameworks relevant to PD is explained in this chapter in brief (PMI 2013, Murray 2009).

2.3.1 Risk management based on ISO 31000 principles

The principles of RM help in mainly creating value and philosophy in the RM process altogether. These principles set by ISO 31000 help to support the comprehensive and

coordinated viewpoint of risk that can be implemented in the entire organisation at all levels. It is the principles that underpin the framework and the process of RM (ISO 31000:2009, Gjerdrum & Peter 2011). The 11 principles from ISO 31000 are mentioned below (ISO 31000:2009, p7):

- Create and protect the value
- Be a vital part of all organisational processes
- Be part of the decision making
- Explicitly address uncertainty
- Be systematic, structured, and timely
- Be based on the best available information
- Be tailored
- Take into account human and cultural factors
- Be transparent and inclusive
- Be dynamic, iterative, and responsive to change
- Facilitate continual improvement of the organisation.

All the principles, other than the "human and cultural factors", "Best available information", and "facilitate continual improvement of the organisation" explains guidance on how RM initiatives should be planned and designed. Whereas the "Human and cultural factors", "best available information", and "facilitate continual improvement of the organisation" are related to the operation of the RM in the organisation (IRM 2018).

2.3.2 Risk management based on ISO 31000 framework

There is a very close connection between RM principles and RM framework. The principles explain what must be followed to achieve effective RM, and the framework provides information on how to make active RM. The RM framework mainly focusses on integrating the management of risk into the organisation's decision-making process (IRM 2018). This framework not only focuses on the required elements for the framework but also describes how the organisation should create, implement and keep these elements well updated and help manage risks effectively by the utilisation of the RM process (IRM 2018, Leitch 2010). As per the definition from ISO 31000, RM framework is a *"Set of components that provide the foundations and organisational arrangements for designing, implementing, monitoring, reviewing and continually improving RM throughout the*

organisation" (ISO Guide 73:2009, definition 2.1.1). The following are the elements of the RM framework (ISO 31000:2009, pp. 8-13):

- *Mandate and commitment:* Strategic and hard worked planning to ensure strong and sustained commitment from the management of the organisations in all levels
- *Design of framework to manage risks:* ISO 31000 gives a clear, detailed explanation of how the framework should be designed to manage risks. The essential elements are (1) Understanding the organisations internal and its external context (2) Establishment of a RM policy (3) Ensuring there is accountability, authority and competence to manage risks (4) Integration into all organisational practice and processes (5) Resource prioritisation for RM in the organisation (6) Establishing internal and external communication and reporting to support accountability and ownership of the risk.
- *Implementation of RM:* This step involves the implementation of the framework into the process.
- *Monitoring and reviewing of the framework:* By measuring the performance of the implemented process framework, ensuring control in the RM practices and continuously reviewing the effectiveness of the framework.
- *Continuous improvement of the framework:* From the above step, decisions are taken on how to improve the framework for better RM practices in the organisation. This change should be made to improve the RM culture in the organisation.

2.3.3 Risk management based on ISO 31000 process

ISO 31000 defines the risk management process as *"the systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analysing, evaluating, treating, monitoring and reviewing risk"* (ISO Guide 73:2009, definition 3.1). Figure 4 shows the RM process (ISO 31000:2009, p.14) as per the definition (ISO Guide 73:2009, definition 3.1). The main difference from the traditional RM process and the ISO 31000:2009 standard is that it includes the elements of "establishing the context" and continuous "communication and consultation" (Gjerdrum & Peter 2011). According to ISO 31000 model, the RM process has two main elements that continuously act in the process of RM that are "communication and consultation" and "monitor and review" (Gjerdrum & Peter 2011). The "communication and consultation" should be considered throughout the risk

assessment process, as internal and external stakeholders inputs play an important role in the RM process. The "monitor and review" should also be a continuous part of the RM process, since it ensures control in the process, further information for improvement in the process and detecting the need for change in the process (ISO 31000:2009).

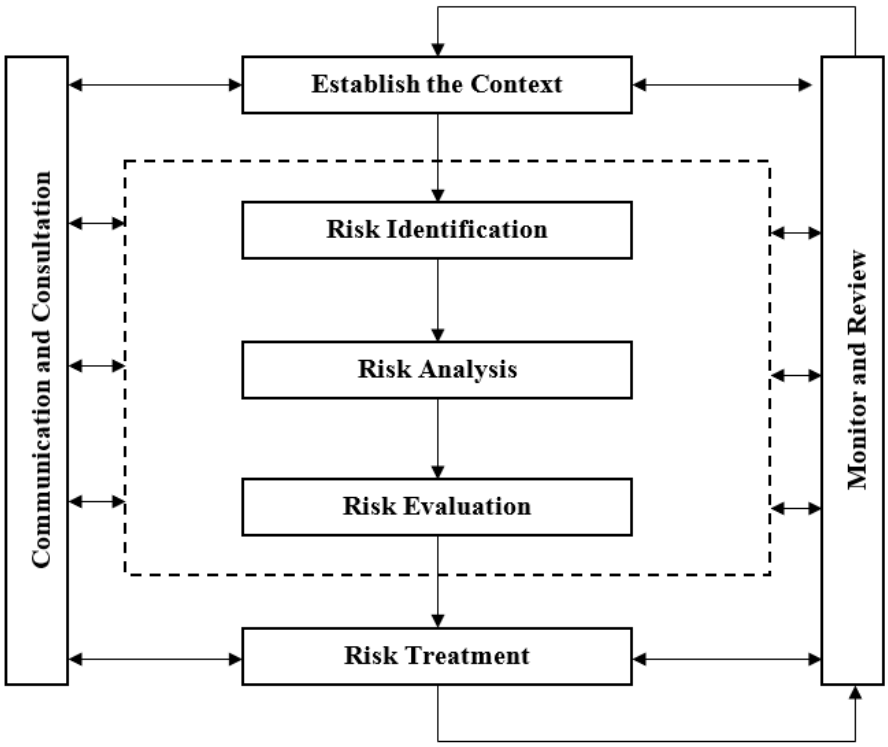

Figure 4. RM process (Modified from ISO 31000:2009, p.14).

"Establish the context" in the RM process can vary according to the structural needs of the organisation. ISO 31000 defines it as "*The external and internal parameters to be taken into account when managing risk and setting the scope and risk criteria for the RM policy"* (ISO Guide 73:2009, definition 3.3.1). The main activities which will be involved in this will be setting RM objectives and defining every level of responsibilities, scope, depth and breadth of the RM process (ISO 31000:2009, Gjerdrum & Peter 2011). This makes "establishing the context" a critical step in the RM process because it helps the organisation confirm their RM approach with regard to the set objectives. It is important for the organisation to establish an internal and external context to achieve objectives like in-depth analysis on the internal and external stakeholders' perception, environment, economic, financial, current trends, skills and capabilities of the organisation, the culture of the organisation, resource availability, and output from the RM process. These factors should ensure to support the RM process to provide the right governance that can impact the objectives of the organisation (ISO 31000:2009, Gjerdrum & Peter 2011). Hence

establishing the right context can help organisations take an efficient decision (IRM 2018).

"Risk identification" is the *"process of finding, recognizing and describing risks"* (ISO Guide 73:2009, definition 3.5.1). It is also mainly about understanding the source of the risk, the potential areas of impact and the potential consequences because of the risks (ISO 31000: 2009). The main objective in the RI is to identify and build a list of risks that can occur and at the same time, risks that can be considered as an opportunity (Gjerdrum & Peter 2011). For RI, there is a need for a systematic process on understanding: what, how, when and why could the risk happen (Purdy 2010). With an unclear objective, it is challenging to identify activities that may give rise to risks that would obstruct the success of the organisation's strategy or objective.

"Risk analysis" in purpose is to analyse the identified risks and to develop an understanding of the particular risk (ISO 31000:2009), which includes the root causes, consequence and likelihood of the risk to occur (Gjerdrum & Peter 2011). ISO 31000 doesn't mention whether qualitative and quantitative methods are preferred for risk analysis. ISO 31000 defines *"risk analysis as a process to comprehend the nature of risk and to determine the level of risk"* (ISO Guide 73:2009, definition 3.6.1).

- The method in which the likelihood of risk is expressed and combined to determine the level of risk must reflect the type of risk, data and the purpose for which the risk assessment output is used. It should be reliable to the risk criteria.
- It is important to consider the confidence in defining the level of risks, and the risks sensitivity to the preconditions and assumptions should be taken in consideration in the analysis, and these factors should be well communicated with the stakeholders and decision makers.
- Risk analysis can be taken depending on the risk type or level, information data available and resources available. Hence the analysis can be qualitative, semi-qualitative, quantitative or a combination of all depending on the situation or circumstances (Purdy 2010).

"Risk evaluation" is a *"process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable"* (ISO Guide 73:2009, definition 3.7.1). Risk evaluation is done to review the analysed risk from the risk analysis process and also review the criteria and tolerance to prioritise the risks and

make sure to use the appropriate risk treatment methods. At this stage, the organisations legal, regulatory, internal and external environment will be considered. Hence it helps organisations to take decisions on how to move to the next stage on treating risks (Gjerdrum & Peter 2011). In this stage, the likely risk exposure to the business and the potential opportunities are understood. The aim of this process is to assess the threats and opportunities to the business in terms of the whole business or a specific project (Chapman 2011).

"Risk treatment" is about selecting one or more options for modifying the risks and implementation of those options to mitigate those risks. To finally treat risks well, communication and consultation should happen continuously, and RM won't be successful if there is no consultation and engagement of stakeholders in the RM process (Gjerdrum & Peter 2011). Risk treatment as per ISO 31000 states that *"the selection of risk treatment options involves balancing the potential benefits of introducing further risk treatment (controls) against the associated cost, effort or disadvantages"* (ISO 31000:2009, p.19). Hence during the process of risk treatment, it is essential to know the timescale and identify the responsibilities for implementing the selected risk treatments (IRM 2018).

2.3.4 Other external RM frameworks

RM framework by Projects in Controlled Environment (PRINCE2)

PRINCE2 contains a chapter on risks, where it explains the RM approach from the Office of Government Commerce (OGC's) publication on the *management of risk: Guidance for practitioners*. As per PRINCE2 risks are defined as the *"an uncertain event or set of events that, should it occur, will have an effect on the achievement of objectives"* and in terms of projects it is the project objectives that are in risk and to achieve an effective RM it is important to systematically identify and assess risks and then plan on implementing risk responses in other words controlling the risks. The UK Government uses PRINCE2 and also by private companies in the UK and internationally. PRINCE2 suggests a five-step procedure in assessing risks that are explained in brief (Murray 2009):

Identify: The main aim of this step is to identify the context of the project and gain information to understand the risks that can impact the objectives. This can further help

in planning an RM strategy for the project on how to manage the risks during the process of the project.

Assess: This step involves assessing the threats and opportunities in terms of probability and impact. The likelihood of occurrence can be prioritised in this step. Risks can be estimated by using techniques like probability trees, impact grid, Pareto analysis, expected monetary value and also evaluation methods like "Monte Carlo simulation" and "what if" scenarios.

Plan: In this step, specific management responses to the identified threats and opportunities are prepared. This is to ensure that the project is not taken into surprise when the risk occurs.

Implement: In this step, the planned risk response steps are taken into consideration and implemented. The effectiveness of the risk is monitored, and corrective action is taken where responses do not match expectations. There is a need for a risk owner and a risk actioner to conduct this process successfully.

Communicate: In this step, the threats and opportunities are continuously communicated with the project and the external stakeholders involved. Communication can be done by reports like checkpoint reports, highlights reports, end-stage and end project reports etc. However, other communication methods, such as bulletins, notice boards, dashboards, discussion threads, briefings, can also be used. Communication can help risks not remain static, and new risks can be identified.

RM framework by PMI handbook

According to PMI (2013) project risk is defined as "*An uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost, and quality"* (PMI 2013). The PMI handbook proposes an RM process framework in a chapter named "Project Risk Management" which includes six steps on the assessment of project risks that are: Plan risk management, identify risks, perform qualitative analysis, perform quantitative analysis, plan risk response, monitor and control risks.

The primary objective of this process framework is to increase the likelihood and impact of positive events and vice versa decrease the likelihood and impact of negative events. The process begins with the (1) process of defining how to conduct RM activities for the project after which (2) the process of identifying the risks that can impact the project are listed, and the characteristics of each risk are documented. Once this process is completed (3) qualitative analysis is conducted by prioritising the risks for the next step analysis by assessing the probability of impact and occurrence. Once this step is done (4) quantitative analysis is done to understand the impact of the risk on the overall objectives to be a success, the organisation should continuously address RM proactively and consistently throughout the project. Then a plan on how to respond to the risks are created in which options and actions are developed to enhance the opportunities and reduce the risks of the projects. Finally, these risks are controlled and in this stage implementation of risk response plans, tracking identified risks, monitoring of the residual risks, identifying new risks, and evaluating the risk process effectiveness throughout the project is conducted, which improves the risk approach throughout the project life cycle to continuously optimize risk responses (PMI 2013).

2.4 Risk identification techniques

2.4.1 RI methodology

This chapter mainly identifies the various RI techniques used to determine risks in projects studied by different authors. According to the Institute of management of accountants IMA (2007) to utilise efficient RI techniques, it is also important to have the right amount of data, and the utilisation of the right techniques solely depends on data availability (IMA 2007). As mentioned by ISO 31000, *"risk identification can involve historical data, theoretical analysis, informed, expert opinions, and stakeholder's requirements"* (ISO Guide 73:2009, definition 3.5.1).

Piney 6 phase methodology for RI:

Piney (2003) suggests 6 phases in the RI cycle that are shown in figure 5 as follows. Here "template specification" mainly involves in defining the "risk statement" which involves the effects, causes, impacts, the area of risks and event. The next step is the "basic identification" which helps in getting an initial view on the success and failure of the project. The strength, weakness, opportunity and threat (SWOT) analysis is said to be a

famous tool used in this step. The second phase "detailed investigation" gives a comprehensive understanding of project uncertainties and the identification from the first step triggers in-dept RI in this stage (Piney 2003). Few of the famous techniques used in the detailed investigation step are interviewing, brainstorming, Delphi technique, document review and assumption analysis (Piney 2003, PMI 2013).

In the "external cross-check" phase, a fairly amount of risk list is already available in hand. However, these risks are based on information from within the project. This step helps identify risks beyond the project as well. Risk checklist and risk breakdown structure (RBS) are said to be useful techniques in this stage. The next step that is the "internal cross-check" which mainly involves validating the identified risk list against the scope of the project. Piney (2003) suggests utilising a work breakdown structure (WBS) to check if the identified risks have been considered from the WBS context. Finally from the well defined identified risk list, i.e., in the statement finalising phase all these risks are understood in terms of effects, causes, impacts, area of risks and event and various techniques are utilised to identify each element. For instance, flowchart is said to be a good RI technique to investigate a risky area, and when the impact of the risk is known, diagrammatic techniques like fishbone diagram is used to determine the root causes of the risks and when the potential causes are known, influence diagrams is a good identification technique to check the potential affects in your plan (Piney 2003).

Figure 5. Phases of RI (Modified from Piney 2003)

Hillson's metalanguage:

The success rate of projects is profoundly influenced by the collaboration of one or more techniques, and there is no one best method for risk identification (Hillson 2002, Rostami 2016). Hillson (2009) provides a 3 part structured metalanguage on the identification of risks *"As a result of <definite cause>, <risk> may occur, which would lead to <effect on objective(s)>"* – The main purpose of using the risk metalanguage technique is to ensure that the RI process identifies risks and distinguishes risks from their cause and effects. The risk metalanguage ensures to create a distinction in risks to prevent confusion later in the risk process (Hillson 2009).

RI technique by utilising three tenses:

On the other hand in one of the briefing papers, Hillson (2006) mentions on the utilisation of the RI techniques by implementing it in 3 tenses, which fall in 3 different perspectives of time – past, present and future. Firstly, the past refers to the historic review of the risks that have occurred in the past. This method helps in questioning managers to ask themselves whether risks which were identified in the past may arise in their current project. Secondly, the present which refers to the current assessments, which focusses on analysing what exists today and does not rely on outside reference points, unlike historical review.

Techniques used in this step help in analysing the current situation characteristics against the given objectives, strategies and models to expose area's that can be uncertain. The third is the future technique that can be referred to as the creativity technique which involves in encouraging people to think creatively to identify the possible risks that can impact the business in the future on achieving the current objectives set by the organisation. These techniques are usually effective when done in a group with the help of a facilitator. The combination of all these techniques can give a broader perspective in identifying risks (Hillson 2006).

Important factors before the utilisation of RI techniques:

However, before taking into account the techniques used to identify risks, it is essential to take down the following factors to identify risks (IMA 2007, Hillson 2002, ISO 31000:2009):

- The RI process should be a risk language precisely for the activity or the process (IMA 2007, Hillson 2002).
- It is always better to use a combination of techniques than rely completely on one single technique (Hillson 2002).
- The technique selected should be open for discussion as every opinion will matter in terms of identifying the list of risks involved. Hence individuals shouldn't fear to give their inputs on the potential issues that may cause impact, which may lead to a significant loss to the company (IMA 2007).
- The RI process should be cross-functional and with a diverse team (ISO 31000:2009)

- Finally, the method may end up giving a large number of results. The key focus is to funnel down the risks to a "vital few" rather than the "trivial many" (IMA 2007).
- The RI techniques utilised should suit the objectives, capabilities and the risks faced by the organisation (ISO 31000:2009, IMA 2007).
- It is important to consider people with the best knowledge to identify the risks during the RI process (ISO 31000:2009).

2.4.2 RI techniques

There are several techniques used by organisations to identify risks in projects, however before considering all the methods it is important to take note that an organisation should not rely on only one technique as every technique can identify different kinds of risks with cross-functional teams working together in order to bring out a list of risks and mainly narrow it down into the ones important for the organisation (Chapman 2011). The key advantage of the entire risk identification process is not only about identifying the risks but also documenting existing risks, and the knowledge and the ability the documentation provides the project team to handle future anticipated risks (PMI 2013)

Brainstorming:

Once the objectives are set clearly and is well understood by the participants of the brainstorming session, there can be a creative generation of a list of risks by each participant on the whole (IMA 2007). The participants are collaborators, who work together as a team to articulate the risks that may be known to the other members of the team. This process is done under the supervision of a leader either by traditional free form brainstorming session or structured mass interviewing session. In some organisations, the facilitators are trained and certified to conduct the brainstorming session (IMA 2007, PMI 2013).

The participants must have the assurance to pool in any idea that pops in their head that will not be led to humiliation or demotion. Once all the list of risks is generated, using the help of a group software, the risks are boiled down to the top few risks. This is done by each participant voting anonymously on the objectives of the risks (IMA 2007). Also, studies by Chapman (1998) indicate brainstorming as the most widely used techniques by organisations (Chapman 1998). The advantage of this technique is that people

stimulate others to bring out more value in the session by identifying more risks, but on the other hand one is not sure if all risks are considered (Halman & Keizer 1994). Participants need to have skills and knowledge when using this technique. In addition to which this technique is suggested to be done under a moderator for an effective brainstorming session (ISO/IEC 31010:2009).

Delphi technique:

The technique begins with the facilitator using a risk questionnaire to ask ideas about the critical risks to consider in the project from the experts who participate in this technique anonymously. The Delphi technique is a method to reach a consensus from the risk experts (PMI 2013). This technique can be used at any stage of the RM process (ISO/IEC 31010:2009). The responses are summarised and recirculated for further comments from the risk experts. Hence the agreement may reach after few rounds of this process, however, though in practice it usually doesn't go beyond the second round. The main advantage of this multi-stage process is that it reduces bias in data, and one person's decision won't influence the entire process. In addition to that, participants also have the opportunity to continuously revise their opinions (PMI 2013, Chapman 1998). The limitation of this technique is that it is time-consuming, and participants need to be explicit in addressing their risks (ISO/IEC 31010:2009).

Nominal group technique

It is a silent technique which works around a group, where the participants write down the ideas related to the problem in a pad or paper and each participant then presents his/her idea in front of the group. This process continues until all the participants are run out of ideas and during this process, the ideas are all recorded. Finally, each writes down their evaluation on the most impactful risk by rank ordering or rating, and finally, these ranked risks are mathematically aggregated to come to a group decision (Chapman 2011, Delbecq *et al*. 1975).

Checklist analysis and risk breakdown structure:

Checklist analysis is developed from past historical data and knowledge that has been collected from past similar projects and other sources. From the lowest level of risk breakdown structure (RBS), the checklist can be prepared, and risks can be attempted to

be identified from the risks not appearing in the checklist (PMI 2013). According to studies, some medium-sized companies created a checklist from RBS as a source which helped in understanding the risks better (Rostami 2016). This allows managers to capture lessons learnt from past projects and assess the similar risks relevant to the present business activity (Chapman 2011).

The RBS is also an influential risk identification, assessment and reporting tool. It has the ability to roll-up or drill-down to the appropriate level of risks and gives new insights into overall risk exposure (Hillson 2003).

***Root cause analysis**:*

Root cause analysis technique as the name suggest can help in identifying a problem and go deep into the underlying causes of that particular problem and take subsequent preventive actions. (PMI 2013). The root cause analysis (RCA) can also be done using scenario analysis, by utilising supporting documents and defining the root causes on what drives the risks in the influence diagrams and interviewing the risk owners who own each part of the risk (IMA 2007). RCA and RBS have similar attributes, which mainly aims in exposing the most prominent source of risks (Hillson 2003).

Assumption analysis:

Assumption analysis is one of the most common RI technique in terms of information gathering (Rostami 2016). Assumption analysis is a technique similar to scenario analysis where a set of hypothesis, scenarios or assumptions are taken in consideration to be applied in the project, and this helps managers identify risks of the project (PMI 2013).

***Structured or semi-structured interviews*:**

This technique can be useful when it is difficult to gather people around like the brainstorming session (ISO/IEC 31010:2009). Interviewing, in general, can be a formal or an informal technique in obtaining elicit data from the project participants, sponsors, other executives, and subject matter experts who can aid in identifying risks in a comprehensive perspective (PMI 2013). Interviews can be conducted in 2 methods of structured and semi-structured interviews methodology. In the structured interview, risks are identified when the interviewer prepares a set of questions on one focus area and

ensures the interviewees view the situation from a different perspective to identify risks from that perspective. On the other hand, semi-structured interviews give more cope for the conversation to explore more in-depth details on the particular focus area. It is very similar to the structured interviews. The main disadvantage of the structured and semi-structured interviews is the time-consumption (Chapman 2011).

System dynamics:

According to Chapman (2011) *"a way of studying the behaviour of industrial systems to show how policies, decisions, structure, and delays are interrelated to influence growth and stability*". The system dynamics is a model creation technique that gives a representation of real-world systems which studies the dynamics or behaviour of the system, which, in turn, helps in the improvement of problematic system behaviour. The visual representation of the model helps in not only identifying loopholes in the system, but also relationships between different events can be grasped (Chapman 2011).

Failure mode effect analysis:

Failure mode effect analysis (FMEA) is a RI technique which is highly used in the product design point of view. This technique identifies the potential failures in different parts of the system and the effects these failures can have on the system and helps in understanding how to avoid or mitigate failure on the system (ISO/IEC 31010:2009).

Quality function deployment (QFD):

Quality function deployment (QFD) is a method that ensures customer or stakeholder satisfaction and value proposition to the customer by adding value for new and existing products in terms product design, and this is done from different perspectives and different levels by understanding the customer needs or stakeholders' requirements (ISO 16355:2015). Few authors consider this a risk factor in terms of technology risks on not integrating marketing feedback into product design. The QFD is an excellent tool to help identify the need for changes in the product design (Cooper 2019, Unger & Eppinger 2009).

PESTEL analysis:

The PESTLE analysis can be done as a part of the brainstorming session. PESTLE is abbreviated as “political, economic, social, technological, ecological and legislative” factors and is mainly used to assess the external market (Chapman 2011).

SWOT analysis:

This technique helps in analysing the strengths, weaknesses, opportunity, and threats (SWOT) of a particular project and often used for the formulation of strategies (PMI 2013, IMA 2007). This analysis helps in bringing together the results of both internal and external analysis. The strength and weaknesses are usually internal to the company like the company’s culture, structure, financial, human resources. Whereas threats and opportunities are mainly the variables outside to the company that is the external environment, which is typically not under the control of the company (Chapman 2011, IMA 2007). This analysis also helps in utilising the organisation's strengths identified to balance off the threats and also identify opportunities to overcome weaknesses (PMI 2013).

Expert judgement:

Utilising the experience of an expert in a particular project can help in identifying risks. The manager has to identify such experts and invite them to study all the aspects of the projects and give possible suggestions on the risks involved (PMI 2013). Also, according to the survey conducted in SME’s expert judgement was practised because of the affordability of resources in terms of time and budget, also the results were valuable, and the procedure was quick and uncomplicated (Rostami 2016).

Risk questionnaire and risk survey:

A risk questionnaire helps to elicit through a set of questions structured in a logical manner reflecting something the participants can relate to and which in turn gives rise to issues related to risks or uncertainties (Chapman 2011). The risk questionnaire consists of internal and external events that can be utilised to identify risks effectively. The risk questionnaire can help companies think through their own risks by providing a list of question around certain kinds of risks. However, the disadvantage is that they are usually

not linked with strategy, and if the questionnaire is too lengthy, a risk survey can be conducted in all levels of management (IMA 2007). The following table 2 shows an example of the risk screening questionnaire that can be asked at an ESNPD process to identify and analyse risks under the different categories of risks (Thäuser 2017).

Table 2. Risk questionnaire at an ESNPD (Modified from Cooper 2019, Thäuser 2017)

	Market risks	Technical risks	Organisational risks	Commercialisation risks
Discovery and Scoping	***Preliminary market assessment*** *Is the potential of the market assessed? *Have the desired product attributes assessed? ***Product definition*** *Is the target market defined? *Value proposition of the product? *Position strategy (Target price) *Product features, attributes & requirements understood by the market	***Preliminary technical assessment*** *Has the technical appraisal been checked? *Has the technical feasibility of the product been considered *Has the technical risks of the product identified *Has the product been checked for IP rights?		
Build a business case	***In-depth market study*** *Has detailed market research been conducted? *VoC taken into consideration?	***Detailed technical assessment*** *Has the in-depth technical appraisal been conducted? *Has proof of concept issues been resolved? *Issues of product meeting safety, environmental, & regulatory?	*Is the team goal oriented? *Team competence	*Have sales projections been conducted? *Have financial analysis been conducted? *Resource requirements of the product been planned?

Fault tree analysis:

As per ISO 31010:2009, the fault tree analysis (FTA) is an applicable tool in terms of RI (ISO 31010:2009, Table A.1). This technique is a diagrammatic technique which works in a logical tree sequence in determining ways in which events can occur through the identification of the faults, methods on reducing the risks are taken into consideration (ISO 31010:2009).

Other techniques:

There are various other possible techniques to identify risks as well like value chain analysis, benchmarking with similar and dissimilar organisations, system design review, process analysis and also utilising external consultants in giving inputs of the identified risks in other companies and challenging the risks identified by the company (IMA 2007).

Scenario analysis:

Scenario analysis is said to be a useful identification tool when the risk situation is decidedly less defined. However, it also helps managers to examine the financial statements for instance based on having an optimistic view of the likely upcoming events, a pessimistic view of the future events and a most likely view on the anticipated future events. This helps managers to understand scenarios on the downside and upside risk potential associated with an activity or project. This is said to be a useful tool in the entire Risk assessment process (Chapman 2011, IMA 2007). Also, according to one of the studies, the most frequently mentioned methods used by practitioners and corporations were scenario planning (Hammoud & Nash 2014). The scenario analysis can be extended to a "what if scenario" modelling technique where the analysis of the question can be "What if the situation represented by scenario 'X' happens"? And further, a network analysis diagram is prepared with different scenarios to assess the feasibility of the project (Chapman 2011).

Cause and effect diagram:

The cause and effect diagram are one of the most famous diagrammatic technique in assessing risks. The PMI handbook considers the cause and effect diagram as a useful RI tool mainly to determine the cause of the risks (PMI 2013). On the other hand, according to Oehmen *et al*. (2010), the cause and effect diagram is considered as a useful risk analysis tool to analyse uncertain events (Oehmen *et al*. 2010). It is also recommended by the (ISO 31010:2009) standards as well. This technique helps aggregate singular risks into larger frameworks and gives a better understanding of the situation, and the data collected in this stage can help in the risk evaluation stage (Oehmen *et al*. 2010).

2.5 Risk management at an ESNPD

This chapter gives an overview of what are the critical risk management (RM) categories related to PD and the common risks identified at an ESNPD from the past literature, which is shown in section 2.5.2 and 2.5.3. In addition to that, Section 2.5.4 shows the various RM process frameworks relevant to NPD.

2.5.1 General introduction to RM in NPD

According to Cooper (2017), risk avoidance in NPD is impossible, until and unless the companies decide to stop innovating (Cooper 2017). With the promise of increased sales, market shares and profits as a necessity for many innovating companies, the products can fail in the whirlpool of technical complications, cost overruns and neglected or missed market opportunities. This is where it is crucial for companies not only to focus on the end new product but also focus on mitigating the PD risks during the process (Unger 2003). RM is directly connected to the success of the PDP. The management of the PDP requires an excellent, reliable method for assessing risks and the obstacles for a product to develop (Wagner 2008). There is no clear-cut reason to pinpoint on what is the success factor or failure to ease RM due to the lack of product definition on what makes a product successful and what leads to the failure of the product.

Quality of customer information plays a vital role in understanding the customer needs in the product development process, and one of the ways quality customer information can be achieved is when the customers are embedded in the PDP , which improves the quality of data retrieved from the customers (Bonner 2010). Also, RM is suggested to be supported by business intelligence systems to gather strategic information, and that can help in establishing the context of RM with a good RM methodology (Ricondo *et al*. 2006).

When considered from the design point of view, with the increase in the information in design from the concept stage to the system level design stage, the uncertainty decreases, and the impact on the cost decreases as the product development process moves from one phase to the next phase. Hence it is essential to mitigate and identify risks at an early stage itself. Therefore, it is also important to produce useful information in the PD process to lessen the uncertainty and risks involved. The following figure 6 gives an understanding that shows the risk as a function of importance to gain helpful information in the PD

process (Wagner 2008, Browning *et al*. 2002). This also implies that during the beginning of the project at the idea generation stage, the amounts of stake are low, and uncertainties are high. As the project progresses, the cost of the project increases with the increase in stake simultaneously. Hence it is important to manage the risks successfully and reduce the uncertainties as for the stake of the product development project increases. Striking a balance between the uncertainties and stake plays an important role (Cooper 2017).

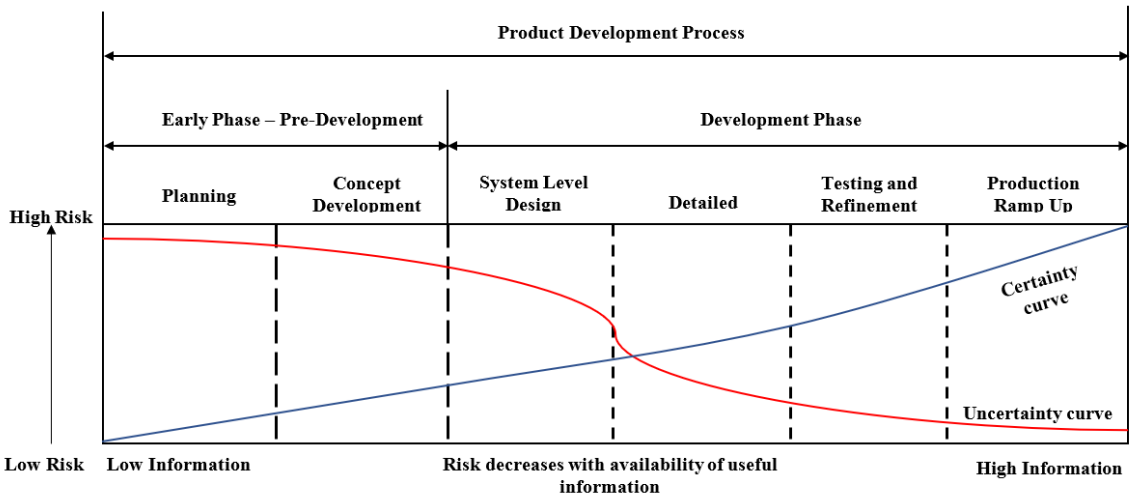

Figure 6. Risk certainty and uncertainty in the NPD process (Modified from Wagner 2008, Browning *et al*. 2002, Ulrich & Eppinger 2008)

The key to managing risks is to manage the likelihood of occurrence of the risks and constantly managing or reducing the impact of these risks during the progress of product development. To manage risks effectively, it is important to begin early in the project and to keep the risks under control by managing the likelihood of occurrence. It's always suggested to manage risks proactively than a reactive manner for successful PD (Smith 1999). In product development, risks are inevitable, and it makes no sense to not consider in the development process. In PD, most of the organisations have a misconception that risks can only be applied from the technical point of view.

However, it is suggested to be applied in every aspect of PDP. Few of the other risks that can be considered are "risks of the product entering the market with a good risk treatment plan", "failure in the supply chain process", "manufacturing risks" and many other risks. Hence considering risks beyond technical risks in product development is important as it helps in discussing every aspect of juicing out profits from new products into the market (Mu *et al*. 2009). For instance, the application of value principle from lean into RM in PD helps in understanding who are your internal customers required for planning, decision

making and also supports in creating transparency in uncertainties. (Willumsen *et al*. 2017). There exist many risks and uncertainties in project risk management. However, the following shows the RM matrix for risks appropriate to the stage gate process from idea to launch of the PDP as follows in table 3.

Table 3. Risk matrix for different types of product technologies and markets (Cooper 2017)

		Product/Production		
Market/Customer		**Existing operations and technology process**	**Operation and technology process is new to the organisation (Can be outsourced as well)**	**Product/Production is entirely new for the organisation**
	Existing market and customers	Overall low risk	Moderate tech and low market risks	High tech risk, low market risk
	New market and existing customers	Low tech and moderate market risks	Overall moderate to high risks	High tech and reasonable market risks
	New market and new customers	Low tech and high market risks	Moderate tech and high market risk	Overall exceptionally high risk

Various authors have various ways of categorising risks in the NPD process. Klink et al. (2001) categorises risks in product development into three main categories that are the technical, market and organisational risk category (Klink et al. 2001). According to research conducted by Keizer *et al*. (2005) in the world's leading fast-moving consumer goods companies around 142 risks were said to be identified in which these risks were further clustered into 12 risk categories (commercial viability risks, competitor risks, consumer acceptance and marketing risks, public acceptance risks, intellectual property (IP) risks, manufacturing technology risks, organisational and project management risks, product family and brand positioning risks, product technology risks, screening and appraisal risks, supply chain and sourcing risks, trade customer risks). Out of the above-identified risk *"consumer acceptance and marketing risks"* was the most frequent ranked risks followed by *"organisation and project management risks"* and other risks like *"commercial viability risks"* on meeting the consumer's standards and demands, *"product technology risks"* were the few top-ranked risks (Keizer *et al*. 2005).

Risk parameter consideration plays a critical role in the management process. Studies show how different risk parameters in NPD like technological risk management, marketing risk management, organisational risk management and commercialisation risk management and the relationship between these different risk parameters can impact the NPD performance and also complement each other to affect NPD performance positively (Salavati *et al.* 2016). Hence, when considering the portfolio of risks in project management or precisely in the product development process, the main categories of risk are technical, market, commercial and organisational risks. Also, when summing up various risk categories identified by authors during their research in the NPD process, it is clear to consider technical, market, organisational and commercial risks and then break them down to sub-categories and identifying factors for every project (Ricondo *et al*.2006). Also, when it comes to the types of risks under each category, it is impossible to separate all of these risks in PD, although categorization of these risks helps in on planning (Oehmen *et al*.2014). According to a survey conducted, technical and market risk categories were considered as the most important and frequent risk (Škec *et al*. 2014). The 4 risk categories are explained as follows:

"Technology risks" are intrinsic risks in the PDP and can involve sub-sections of risks such as the designing of the product, manufacturing technology and intellectual property issues etc. The main risks that exist in the technological risks category are with the product not meeting safety and performance requirements towards the end of the product development process (Keizer & Vos 2003, Cooper 2003). According to Mu *et al* (2009), technology risks pose a serious challenge when it comes to the NPD success, however having a technological orientation can help organisations achieve new technologies to keep up with the technological trend (Mu *et al* 2009). Innovation radicalness and differentiation from the competitors help in staying in a better competitive edge and is said to be the key to the successful marketing of new products (Gatignon & Xuereb1997). The identification of customer needs and requirements can reduce technological risks. The organisation should have the capability of launching new products with new technologies and capabilities refers to human resource, a product owner/ product manager, machinery for manufacturing and time to bring out the new product. Also, reviews from business strategist; marketing strategist can very well help reduce this risk. A survey result also suggests that better control of technology will improve the performance of NPD. Hence technology RM is concluded as a very complex issue in

NPD and organisations should take into account the risk elements in the following conditions as stated by (Mu *et al* 2009):

- *when they do not dominate the technology*
- *when they do not understand the project's means*
- *when they cannot ensure the outcome of the NPD project*

"Organisational risks" is very much related to market research and identifying customer needs. Having a multi-functional team helps in reducing risks in the NPD process, which allows organisations to identify risks at a very early stage (Salavati *et al.* 2016). Recent research has also proved the importance of organisational support in understanding customer requirements. Organisational support will help in cultivating an innovative culture in which new products are seen as a basic necessity for corporate survival. At a point when the product advances and receives support from the organisation, it ought to be implemented for the firm to actualize the NPD strategy in an efficient manner (Jeong *et al*. 2006). On the other hand, to reduce organisational risks, it is also imperative for the organisation to invest in retrieving external and market data (Balbontin *et al*.2000).

"Market risks" mainly deals with understanding what is the type and scope of the customer need in general, and these challenges can be satisfied with new products and new technologies. According to studies, marketing risk is said to be the most critical risk that can directly impact the NPD process and achievement (Salavati *et al.* 2016, Balbontin *et* al.2000). It is essential for a company to be aware of the degree of market risk in the environment as to how it can be dealt with. There are various components that can be the source of market risk and opportunity like demographic trends, legal and political characteristics of the environment, competitor's in the market, change in economic environment, innovation and technological advancement introduces competition for marketing of new products and services, legal and regulatory issues like environmental issues can bring changes in unit cost of production etc. Hence it is important to consider the macro marketing environment to adapt at a micro level (Chapman 2011). Finally, it is decided by the customers whether or not they absorb or ignore a product. Hence this brings into the risks of bringing the product at the right time to the market without delay for the best pricing and selling (Wang & Lin 2009).

"Commercialisation risks" when organisations fail in their ability to introduce and stabilise their newly released product in the market, the rise of commercialisation risk

occurs. Commercialisation risks are to ensure that marketing activities are kept well in control and coordinated in a way to ease the commercialisation process (Salavati, Mu *et al.* 2016). Finance is considered as commercial viability in terms of the risk domains considered in the NPD process (Keizer & Vos 2003). However, in organisational RM, communication within the firm is a critical aspect for acceptance of the idea of the new product to also understand the availability of resources for the development of the product (Thäuser 2017). An organisation should have the ability to collect external data and also adapt to the external environment and transform this data into useful information. Also one of the surveys conducted has proven the significant importance of the commercialisation parameter on the impact of NPD performance and it is suggested that organisations should be able to establish their products in the market and understand the VoC with feedback to take preliminary steps in introducing the product into the market so that it helps in the improvement of sales (Salavati *et al.* 2016).

2.5.2 Risk identified at Early stage of new product development

Technology risks

Intellectual property issues:

In the context of PD, *Intellectual property* means legally protectable ideas, concepts designs, the name of the product, and the necessary processes connected to the new product. There are four types of intellectual properties usually relevant to product design and development, which are patents, trademark, trade secret, and copyright (Ulrich & Eppinger 2008). In any NPD process, there is always the risk involved on whether another organisation already has a patent, property rights for the particular technology or product. It is critical for any company to consider IP risks at an initial stage itself because it may be too late if considered once the resources have been allotted or wasted on the product (Thäuser 2017). According to an analysis done in ongoing NPD projects, personal interviews and surveys by various authors have identified that IP risks are a potential issue to be better solved at the concept development phase/ pre-development stage in the NPD process (Škec *et al*. 2014, Luoma 2008, Keizer *et al.* 2005). The utilisation of an RBS tool in a vaccine development company found intellectual property was one of the potential risk issues to be considered. (Ayala-Cruz 2016, Hillson 2003). The in-depth technical assessment stage suggests performing a detailed technical assessment during the building the business case stage, which includes activities like an in-depth technical

appraisal, establishing proof of concept, intellectual property issues resolution etc. (Cooper 2019).

Technology feasibility risks:

It is essential to consider the technical assessment at an ESNPD. To accept the new product concept idea, it is essential to assess technical feasibility. The principal dimensions of technical feasibility are assessing the cost at a given time, resource availability, strength of firm research and development (R&D), engineering and manufacturing unit skills (Carbonell-Foulquie *et al*.2004). Cooper (2019) considers it to be one of the vital activities of the front-end process and suggests the discovery and scoping stage must conduct a preliminary technical assessment with the appraisal of the project, assessment of technical feasibility and identification of technical risks (Cooper 2019). Decision making can be supported at an EPNPD by identifying the technical maturity, reliability and usability of the product early in the process to prevent commercialisation risks further in the process (Luoma 2008). Risk mapping surveys conducted by other various authors have also identified technical feasibility risks and highly recommends these risks shouldn't be neglected early in the process (Škec *et al*. 2014, Keizer *et al*. 2005, Unger & Eppinger 2009).

Environmental and safety regulations risks:

To avoid legal complications in the later stages of NPD, it is important to consider environmental and safety regulations risks at an ESNPD with the non-misleading interpretation of environmental or safety legislation (Thäuser 2017, Ricondo *et al*. 2006). The environmental and safety regulations risks can be directly linked to damage to reputation/brand risk, which, according to Aon's survey of 2017 is said to be number 1 ranked risk (Aon 2017).

A good example is: a tech worker in China who bought a new electronic device, and his device caught fire during charging which spread in social media within minutes and impacted the reputation of the organisation (Aon 2017). Identification of the potential environmental impacts is a vital step in the NPD design process as every product will eventually have environmental impacts over the life cycle. Design for environment (DFE) is suggested to be considered as early in the NPD process to eliminate or minimize the environmental impact. The main process of DFE includes identifying internal and

external drivers of DFE like product quality, image, operational safety, environmental legislation, setting environmental goals for the product, and finally having DFE team (Ulrich & Eppinger 2012). Also, RBS techniques and other surveys conducted by various authors have found environmental impacts being a significant risk in the NPD process (Hillson 2003, Mu *et al*.2009).

Technical team competence risks

Risks on the changes in technology, skills to handle technology and learning abilities or no strong technical competence or lack of organisational experience by the team members (Park 2010, Hillson 2003). In addition to that, it is essential for the team also to adapt and understand the changes in the technology at an ESNPD (Young 2010). Identification of the technology gap is also considered as one of the most potential risks in the NPD process, according to the survey conducted by (Halman & Keizer 1994).

Market risks:

Identification of competitor risk:

According to HBR, companies need to adapt themselves in the current competitive business environment, and the review also says about companies falling out of their top 3 ranks in their industry has increased seven times in the past five decades because of the increase in competition in the market (Reeves 2011). Also, according to Aon's global risk survey of 2017, increasing competition is considered as the 3rd ranked risk. Competition has become so fierce that companies are finding it a tedious task even to identify the industry and competitors they are competing against (Aon 2017). Also, when considering the RBS research conducted in various sectors, it was found that competitor risk is always an existing external source of risk and cannot be avoided in the market risk category (Hillson 2003, Halman & Keizer 1994). It was found when analysing the management process considering risks and performances in developing new products that there is competition in every aspect of the product like in quality, design, and cost of new products. The competition has increased with new players in established segments and new segments (Park 2010).

Risks on insufficient market analysis:

Inadequate market analysis has been the topped ranked significant reasons for the failure of a product since the early 1960s, according to a survey conducted by the National industrial conference board (Chapman 2011). Cooper (2019) research survey from a random sample of 177 firms in Canada proposed eight factors on the failure and success of a product. Amongst the eight factors, few were the unique superior product which explains the need for unique benefits to the customers and a compelling value proposition to the customer. He also emphasises on understanding the customer needs early in the process by involving the VoC with a good preliminary and detailed market study, market research and VoC research at an ESNPD (Cooper 2019).

Also, one of the risk factors that may jeopardize the successful realization of the project objectives is not identifying the customer demands and value proposition to the customer. However, a market analysis may depend on the type of innovation, like radical innovation and incremental innovation. In the case of incremental innovation, the product is anyway inclined to the current market to which traditional research techniques can be used. On the other hand, for radical innovation market research - more in-depth market analysis techniques like QFD, prototype testing with customers etc. may be needed since its dealing with a new market with new customers altogether (Halman & Keizer 1994, Thäuser 2017). Many other authors according to their survey have also mapped insufficient market analysis as a potential risk in the NPD process at an ESNPD (Škec *et al*. 2014, Luoma 2008, Kirkire *et al*. 2015, Keizer *et al*.2005).

According to a commercialisation risk map survey conducted in the front-end process-innovation market segmentation was one found to be an important finding with other market environmental risks to take crucial strategic decisions (Luoma 2008). To get an in-depth insight into your customer, it is essential to define the target market you are aiming at and understanding the market prospects for the product (Majava *et al*. 2014). The segmentation of customers is done in two levels one is the customer and organisational level. The customer segmentation is done based on behavioural patterns of the customers, psychological, demography and socio-economic profile characteristics and on the other hand organisational segmentation is done by demographical, economic and geographic characteristics (Mariotti & Glackin 2012, Baines *et al*. 2013, Thäuser 2017). External risks can have a massive impact on the project's objectives like cost, quality,

time-schedule, customer satisfaction etc. Park 2010 and Hillson 2003 classifies market risks more as external risks and identifies changing social and economic market issues as a significant risk to consider in the market risk category (Park 2010, Hillson 2003).

Commercialisation risks

The major risks identified by various authors during their risk mapping survey at an ESNPD in terms of commercialisation risks were firstly in the availability of resources. Firstly, it is crucial for the organisation to have a realistic view of their financial resource availability to move ahead with the PDP smoothly without obstructive the objectives of the project (Thäuser 2017). In addition to the financial resource availability – the financial return of investment risks is also taken into consideration at an ESNPD by utilizing techniques like net present value, internal rate of return, the average rate of return. (Ulrich & Eppinger 2012, Chapman 2011, IMA 2007, Cooper 2008).

The financial feasibility risks depend on the planning at the ESNPD, which is solely planned based on the budget, financial scope and management skills (Škec *et al*. 2014). The financial criteria are a common criterion set in the stage-gate process and the NPD process in the pre-development stage. The criteria are shown in chapter 2.1.4. Secondly, the availability of product resources also is an important risk that needs to be identified at an ESNPD according to various authors to prevent overshooting of budget and time-schedules in the NPD process (Ulrich & Eppinger 2012, Kinnunen *et al*.2011, Cooper 2003, Thäuser 2017).

Commercialisation risks increase when the organisation fails to introduce and stabilise the new products in the market. Even estimating the sales forecast of the product is important to be considered early in the process to manage/minimise the risk of product failure post launch of the product. However, it is important to consider the uncertainties and not only rely on past historical data and assumptions. (Oehmen & Seering 2011, Thäuser 2017, De Weck Olivier & John 2007). Forecasting at an early stage of NPD is important, and some of the popular sales forecasting techniques are moving averages, exponential smoothing, time regression, holt-winters model, bass model etc. (Thäuser 2017). However, commercialisation requires resources like technical specifications, industrial experience, customer, market information, the ability to identify the sufficiency of functional, communications and close relationship with key important factors (Aarikka-Stenroos & Sandberg 2009). Commercialisation is considered as the final phase

in the innovation process. However, the effectiveness of the commercialisation is determined from how well the potential of the ideas is developed during the earlier phases. (Beard & Easingwood 1996, Guiltinan 1999, Luoma 2008).

Organisational risks

One of the major risks that were most identified according to various authors in terms of organisational risks were the team communication issues. The organisational risk was said to be the most neglected risk in the NPD process but yet can have an impact in the entire NPD process (Hillson 2003, Thäuser 2017, Park 2010). To manage risks well in the NPD process, it is important to have a cross-functional team involved in assessing various types of risks and studies suggest that the climate and culture in the NPD team can be influential in the success of the product (Thäuser 2017, Kahn *et al*. 2012). Based on the literature study conducted by (Park 2010), he concluded five main risks under the organisational risk category that changed in project requirements, changes in team members during the development process, changing organisational priority, changing management commitment, and conflict within the organisation (Park 2010). Also, the capability of the organisation to adapt to change in complex environments was another risk identified during the NPD process (Mu *et al*.2009).

2.5.3 RM framework relevant in NPD

Also, from the literature in chapter 2.2, the standard RM approach involves risk identification, analysis, evaluation and mitigation from the ISO 31000 standard. In addition to the ISO 31000 framework, other external frameworks for RM have also been explained in chapter 2.2. The ISO 31000 and PMI framework are external RM frameworks, but few authors have come up with different RM approaches relevant to product development in a detailed context like the risk-driven design framework, investigate, communicate and mitigate (ICM) process, integrated project risk and stage-gate innovation process, conceptual framework on NPD and Corning's risk-based contingency model which are explained in brief in this sub-chapter. All these frameworks help to bring a relationship between PD and RM in order to help the PD process to be improved.

Risk-driven design framework:

The risk-driven approach is a method in which it mainly focusses on the management of the design process in the PDP and the integration of this method in the design process. The four principles for a risk-driven approach for successful RM is shown in figure 7 (Oehmen & Seering 2011).

The first principle mainly speaks about the identification of uncertainties in design risks and bring clarity by understanding those risks by quantifying them. Quantification can be done in different degrees from a verbal description of uncertainties with limited possibility of quantification to continuous probability distribution with the best of information available to quantify the risks. All descriptions of uncertainty depending on the reliability input data available, be it expert opinions, stimulations and historic data. The second principle mainly speaks on how transparency can help decision-makers make decisions clearly by setting realistic objectives. Transparency enables the determination of risk-return trade-offs, which creates an opportunity for entrepreneurial decision making. For example, the choice between high performing new technology which gives high return can be balanced with low return medium performance technology. The third principle mentions managers can manage risks in two ways that are by reducing the uncertainties of the underlying risks and their root causes or making the PD system resilient against uncertainties. The overall risk reduction of the projects can be used as a critical key performance indicator by significantly reducing risks as early as possible in the design process (Oehmen & Seering 2011).

To minimise the uncertainties it is important to consider the root cause of the uncertainties as well like company internal uncertainty, supplier-related uncertainty, a customer described uncertainty, market and macroeconomic uncertainty (Bassler *et al*.2011). Finally, the fourth principle speaks about how agility can help a PD system to have a stable performance under varying circumstances. Mainly on detecting errors early and taking appropriate actions for it. Some of the ways to detect errors early and have an agile system in PD is by involving no bureaucracy, no unnecessary activities in the system, flexibility to change objectives for example by buffers for each objective in design like financial buffers, schedule buffers, and regular interaction with customers and user needs understanding by VoC and finally also performance buffers (Cooper 2014, Cooper 2019, Oehmen & Seering 2011).

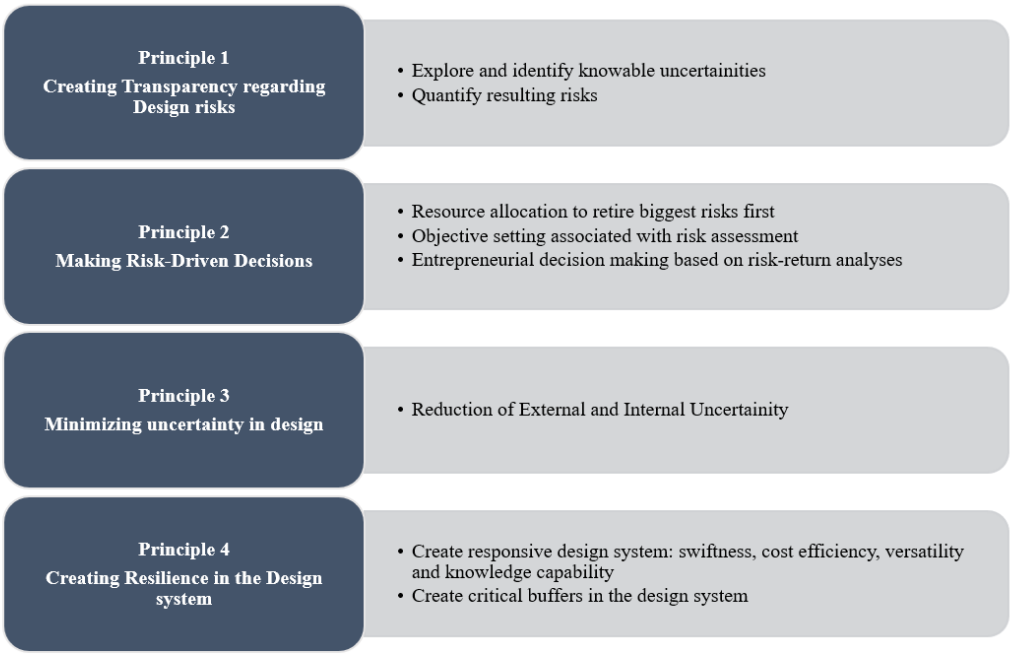

Figure 7. Risk-driven design principle (Modified from Oehmen & Seering 2011).

Investigate communicate and mitigate process (ICM Process):

According to the ICM process, risk mitigation in PD is a 3-step process which involves identification of the risk, communication of the risk and mitigation of the risk, as shown in figure 8 below.

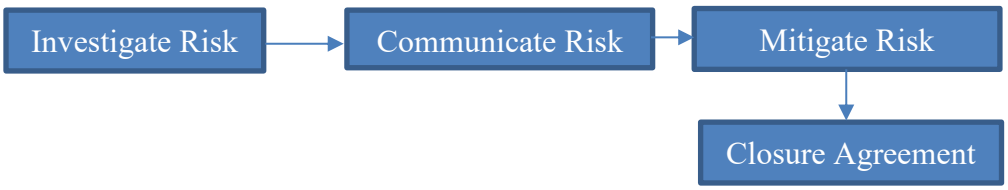

Figure 8. ICM Process (Modified from Levin & Kalal 2003).

The first phase of the PDP begins with the concept development phase and is known as the front-end process (Ulrich & Eppinger 2012). This phase, according to Levin and Kalal (2003), is divided into a product concept and design concept phase. In the first part of the front-end phase that is the product concept phase, five reliability activities take place in this phase according to that are (Levin & Kalal 2003):

- *Establishing the reliability organisation*

  It is critical to have the right staff and culture to implement the reliability process. The reliability team should ensure everyone has a leadership skill and also, of course, a strong technical background with experience.

- *Defining the process*

  It is essential to define the process and tailor the process to suit the particular need, and once the process is described, it is necessary to train everyone about the process.

- *Defining the product reliability requirements*

  The main activity here is setting the product reliability requirement according to customer requirements. It is important to consider aspects, for example, like losing the market share because of unacceptable product reliability, how can the market share increase because of your product, customer expectation, value proposition etc.

- *Capture and apply external lessons learnt*

  In this phase, it is imperative not to commit the same mistakes as the previous programs and learn from the mistakes. There will be internal lessons learnt can be captured and applied in the product design phase. However, it is the external lessons learnt that is important in this phase and some of the focus areas to capture external lessons are conducting an external VoC, past product warnings, reviewing customers past complaint files etc.

- *Risk mitigation*

  In the product concept phase, a risk mitigation plan is created, and the mitigation plan is updated as the process of PD takes place. However, before the end of the product concept phase, a risk mitigation meeting is scheduled to present risks by all functional groups. Since the development cost is less at this phase as compared to the coming stages of NPD. Hence the meeting is helpful in understanding if the project should be continued or cancelled if the product risks are unlikely to meet the market requirements. The risk mitigation meeting acts as a gate in the ICM process.

In the second phase, that is the design concept phase, the same ICM process is repeated to identify new risks and update the risk mitigation process from the previous stage. As the previous stage is more customer-focused, there were very little details known regarding the design in this process. In this stage more, new risks start becoming visible

reflecting on the lessons learnt from customer feedback, complaint files etc. A Pareto chart is used to prioritise the risks, and the mitigation process is repeated. In addition to this internal lesson are also learnt from the past. Finally, a risk questionnaire in terms of design risks helps in looking forward and capturing new risks. The new risks identified may help in managing the risks better if not mitigated completely. The following table 4 shows a risk mitigation form (Levin & Kalal 2003).

Table 4. Risk mitigation form (Modified from Levin & Kalal 2003).

Product concept phase risk mitigation form									
Date: Product Name: Risk owner:									
Investigate			**Communicate**		**Mitigate**				
Item No	Identify and analyse the risks	Risk severity	Date of risk identified	Risk accepted (Y/N)	Mitigation plan	Resources required	Completion date	Success metric	Investigate alternate solutions

Corning's risk-based contingency model:

According to Cooper (2017) organisations need to utilise a risk-based contingency model where the project team starts off with a blank canvas and identifies what are the (1) Key unknows and uncertainties involved in each stage are defined, (2) Pinpoints the critical assumptions in which the assumptions are critical to the project, product design, or business case which may lead to an economic impact and (3) Determines what is the information that is required to validate or verify the assumptions considered in order to mitigate the risks. Finally, through these steps, the key tasks and activities needed in each stage are determined by understanding what is required in order to get the key information. The need for information, in turn, helps define the knowledge gap to be concluded before the next project review, and this helps determine the activities required in each stage, thus defining the deliverables tailored to a specific project. Hence in this method, every project has its custom-tailored methodology to make the process more flexible. However, the only disadvantage in this method is that the project teams must be very experienced to conduct this method. One of the reasons for the next-generation stage gate process to be more adaptive and flexible is to have a risk-based contingency model approach to help appropriate activities and deliverables to be determined based on risks and project assumptions (Cooper 2017).

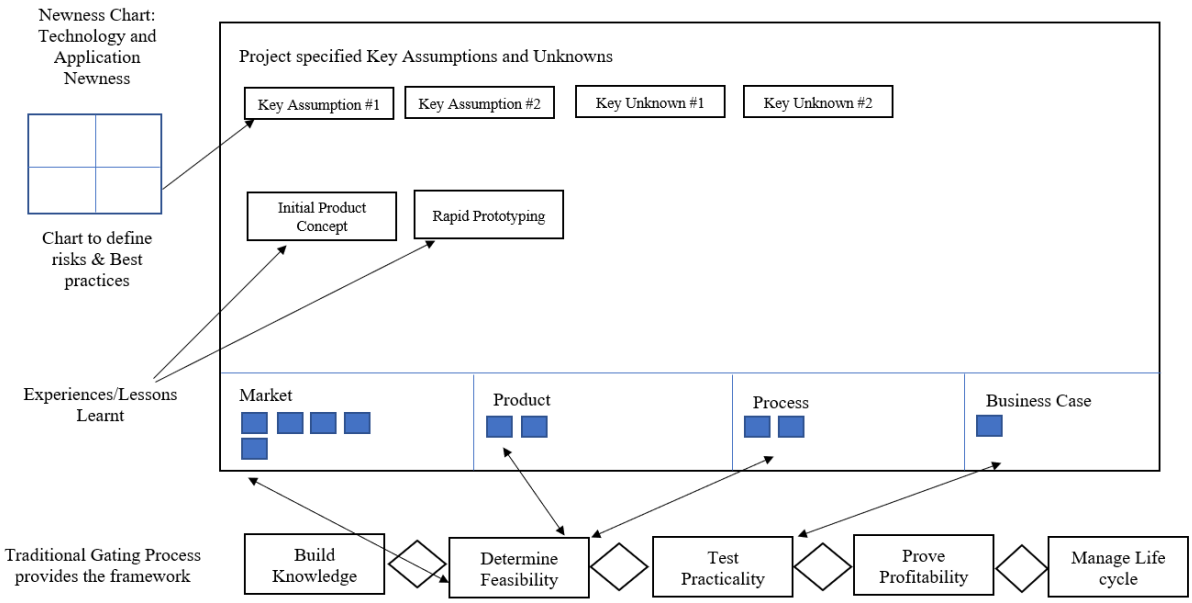

Figure 9. Corning's risk-based contingency model and customized project canvas (Modified from Cooper 2017)

This method was said to be utilised by Gorilla® Glass, which is being used in Apple iPad screens (Cooper 2014). It is important for managers to think systematically on the multiple categories of risks faced so that they can organise processes for each risk to have active and cost-effective RM (Kaplan *et al*. 2012). Figure 9 shows corning's, risk-based contingency model. From the above figure 9, Corning utilises a "blank canvas", which helps map out the subsequent action plans for the project. The main topic area of this canvas includes (Cooper 2017):

- Customer needs, market trends, competition, value proposition
- What are the solutions to be considered?
- Business model to achieve value for this project
- Challenges and risks involved that can impact the project
- Knowledge gaps (Critical unknowns)
- Priority tasks to be considered to reduce the unknows and increase the success
- Key activities on what are the next steps that can be considered (Who should do it, the time required to complete it, and resource requirements)

Integrated project risk and stage-gate innovation process

Every phase of the innovation process can be viewed as a process of gathering information. It is considered that this process of gathering information, analysing it and taking an appropriate management action is itself a form of RM, but project RM makes the entire process more explicit supporting the innovation process and validating the uncertainties in the data at each stage. This risk analysis process helps in understanding the probability of the innovation process on achieving the objectives in each stage, and this helps in identifying new uncertainties needed to be considered in the next stages (Bowers 2014). The criteria in each gate may vary from organisation to organisation, but it is important to consider a criterion at each gate for the success of product innovation (Keizer *et al*. 2002). Each decision taken in each stage determines the forecast for innovation and helps in taking a go/no-go decision whether to move forward with the project or abandon it.

This combined risk management model with innovation can help a diverse set of companies to ensure integration between RM and innovation as per Bowers (2014). The following figure 10 shows a combined model of the stage-gate innovation process and project RM framework. The combined framework shown in figure 10 helps in providing a basis for tailoring RM in different innovation-based industries, and it also puts a light in the possibilities of integration between innovation and project RM (Bowers 2014).

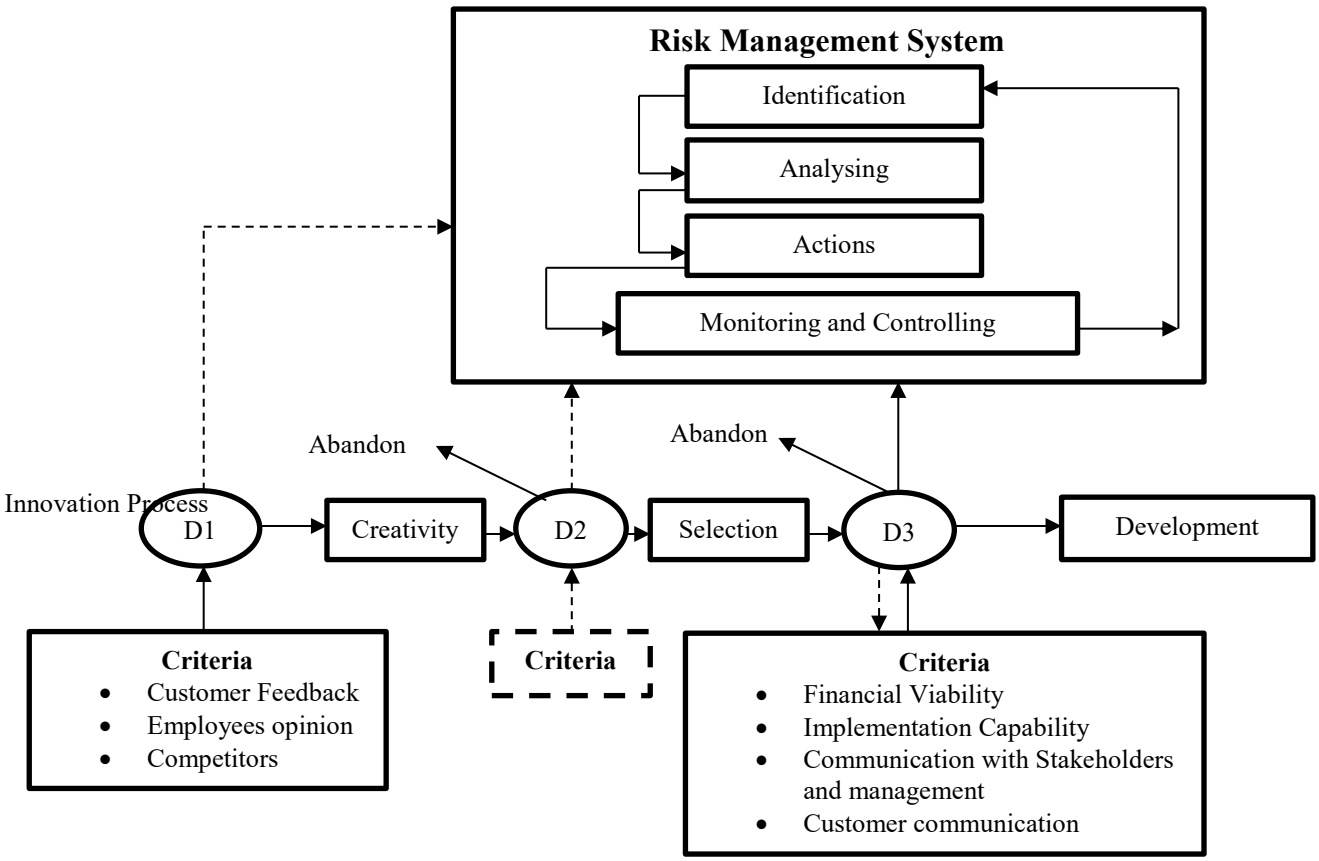

Figure 10. Integrated project risk and stage-gate innovation model (Modified from Bowers 2014)

Conceptual framework on NPD

(Park 2010) developed a framework to manage risks in the NPD process by involving four important factors that are the organisational management system, PD process, RM, outputs influence on the development of new products as shown in figure 11. According to the demand for new product development by the organisation's strategy, the PDP is implemented with the consideration of the organisational management system. The organisational management system is the resource capability like human resource, information technology development, leadership and strategy, knowledge management structure etc.

Before the manager considers in planning for PD, it is essential for the manager to consider the number of risks the manager is willing to tolerate. In the (1) ***first phase*** the idea is generated according to the organisation's vision, goals and objectives and the risk analysis and success analysis and also initial phase cost and gain estimates are tried to be

determined early in the process. (2) In the ***second phase,*** it is important for the organisation to identify the constraints like internal technology, human resource availability and financial condition. Also, the feasibility study is done in this phase to estimate costs and gains and including cross-functional teams, project managers while considering the risks and performance of the new project (3) In the ***third phase*** plans are developed for development of the product like WBS, project scheduling, cost and also planning on how to reduce the identified risks by communicating it with a cross-functional team. (4) In the ***fourth phase*** is the implementation phase with continuous performance measurement of the project, which helps in the reduction of risks and finally transferred to the output phase for feedback and product realisation (Park 2010).

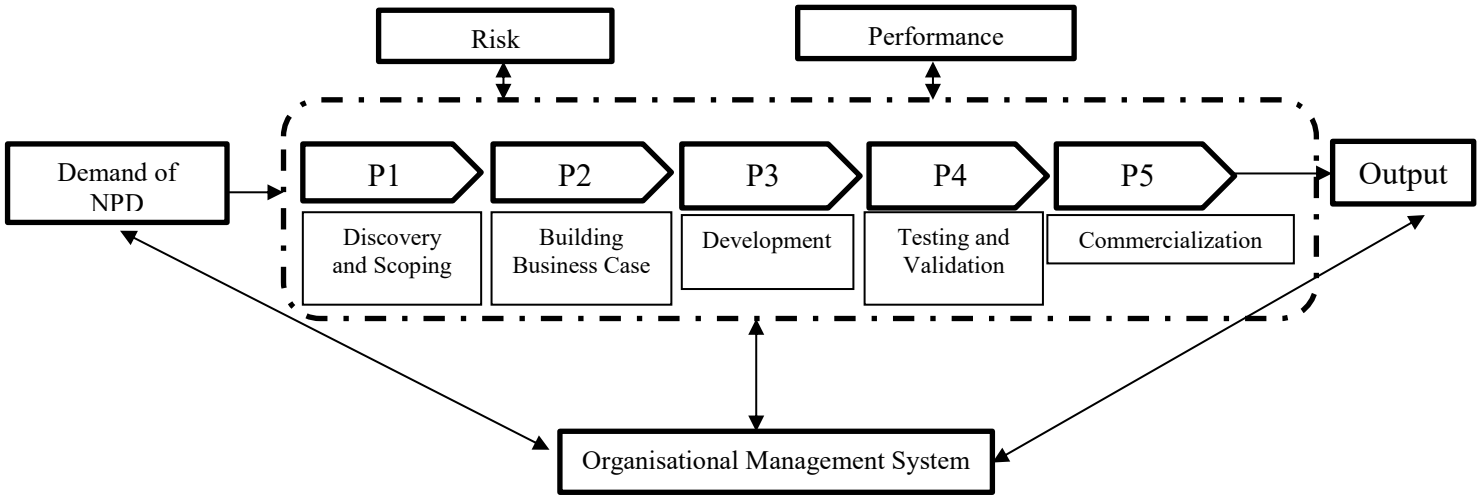

Figure 11. Conceptual framework on NPD (Modified from Park 2010, Cooper 1990)

2.6 Literature synthesis

The Literature review was framed based on the scope available on the foundation concepts of RM and NPD. The foundation concepts extended the literature to investigate and review on the various external RM process frameworks and RM process frameworks relevant to NPD. Furthermore, NPD processes were explained in detail, emphasising more on the ESNPD. In a general context, it was found that most of the researched process frameworks relevant to NPD were similar to the process steps of the ISO 31000 generic standard. Using these foundation concepts, the literature review furthermore investigates in filling the literature gap in the involvement of RM at an ESNPD by researching on the RI techniques available and the various potential risks identified at an ESNPD. The

findings from the literature are further utilised in empirical research in order to validate and enhance the current literature findings to fill in the literature knowledge gap.

RM strategies directly impact the performance of NPD. Consequently, RM is suggested to be considered in the entire NPD process. The four main risk categories considered to be important were market, technical, commercialisation and organisational risks (Mu *et al*.2009, Salavati *et al*. 2016). These four risk categories provide a foundation in the empirical research. Pre-development homework is suggested to be an important factor for the success of a product and how important are the processes at an ESNPD (Cooper 2019). Hence the literature begins with reviewing the basic RM principles, guidelines and processes by various external frameworks (ISO 31000:2009 , Murray 2009, PMI 2013), which then extended the study in researching about RM process frameworks integrated into the NPD process (Levin & Kalal 2003, Cooper 2014, Oehmen & Seering 2011, Park 2010, Murray 2009). It can be observed that the ISO 31000 gave promising and detailed management of risks that can be utilised in any industry based on the framework, principles and processes (IRM 2018, ISO 31000:2009, Purdy 2010). The ISO 31000 also showed similarities in terms of process steps with most of the RM process framework relevant to NPD. The synthesis of RM external and process frameworks relevant to NPD is shown in table 5.

There were many literature knowledge gaps found in the proposed RM process frameworks from various authors. Considering the main objective of the thesis in studying the current state RM practices in PD companies and also integrating risk management at an ESNPD, the central knowledge gap found in the literature was the non-existing on the utilisation of risk assessment techniques to identify, analyse and evaluate risks. RI is the first and most vital step in the risk assessment process in all investigated RM process frameworks. The literature review extended its study in reviewing the various RI techniques that can be utilised to identify risks in the NPD process (IMA 2007, Chapman 2011, ISO/IEC 31010:2009). Various structured RI methodologies are also discussed in the literature (Hillson 2009, Hillson 2006, Piney 2003). The synthesis of the various RI techniques from various authors is shown in table 6. To supplement this, common potential risks were reviewed from various authors which are further validated in the empirical study. Criteria's from chapter 2.1.3 was also taken into consideration (Kinnunen *et al*.2011, Cooper 2008). The risk synthesis on all the risks retrieved from the literature review is listed under each risk category, as shown in table 7.

Table 5. Synthesis on RM process framework

RM external process framework with dedicated processes
ISO 31000 process framework (ISO 31000:2009)
• Communication and consultation • Establishing Context • Risk identification • Risk analysis • Risk evaluation • Risk treatment • Monitoring and review
PRINCE2 (Murray 2009)
• Communicate • Identify • Assess • Plan • Implement
PMI framework (PMI 2013)
• Plan risk management • Identify risks • Qualitative risk analysis • Quantitative risk analysis • Plan risk responses • Monitor and control risks
Tailored RM process framework relevant to PD with dedicated processes
ICM process (Levin & Kalal 2003)
• Investigate • Communicate • Mitigate
Risk driven design framework (Oehmen & Seering 2011)
• Creating transparency regarding design risks • Making risk-driven decisions • Minimizing uncertainty in design • Building resilience in the design system
Corning's risk-based contingency model (Cooper 2017)
• Defining key unknows and uncertainties • Critical assumptions to the product design, project or business case • Determining information needed to verify critical assumptions to mitigate risks
The conceptual framework of NPD (Park 2010)
• Project idea generation • Risk & success analysis • Constraint identification • Feasibility study & resource identification • Project plan development • Implementation
Integrated project risk and innovation stage gate model (Bowers 2014)
• Identifying • Analysing • Actions • Monitoring and controlling

Table 6. Synthesis on RI techniques from literature review

RI techniques
Information collection techniques
• **Brainstorming** (IMA 2007, PMI 2013) • **Delphi technique** (PMI 2013, Chapman 1998) • **Structured and semi-structured interviews** (PMI 2013, Chapman 2011) • **Risk survey (**Thäuser 2017, Chapman 2011, IMA 2007) • **Expert judgement (**Rostami 2016, PMI 2013) • **Nominal group technique** (Chapman 2011, Delbecq *et al*. 1975) • **PESTLE analysis** (Chapman 2011) • **SWOT analysis (**Chapman 2011, IMA 2007, PMI 2013) • **System dynamics** (Chapman 2011)
Historical information techniques
• **Checklist analysis** (Chapman 2011, PMI 2013, Rostami 2016) • **Risk questionnaire (**Thäuser 2017, Chapman 2011, IMA 2007)
Diagrammatic techniques
• **Risk breakdown structure** (Hillson 2003, Chapman 2011) • **Cause and effect diagram (**Oehmen *et al*. 2010, PMI 2013)
Assumption techniques
• **Scenario analysis -What if scenario or SWIFT (**Hammoud & Nash 2014, Chapman 2011, IMA 2007) • **Assumption analysis** (Rostami 2016, PMI 2013)
Product development related identification techniques
• **Failure Mode Effect Analysis (**ISO/IEC 31010:2009) • **Quality Function Deployment** (Cooper 2019, Unger & Eppinger 2009, ISO 16355:2015) • **Fault tree analysis (**ISO 31010:2009) • **Root cause analysis** (PMI 2013, IMA 2007, Hillson 2003)

Table 7. Synthesis on risk identified at an early stage of new product development

Risks identified at an early stage of new product development
Technological risks
• **Intellectual property risks** (Škec *et al*. 2014, Keizer *et al*. 2005, Thäuser 2017, Hillson 2003, Luoma 2008, Ayala-Cruz 2016, Ulrich & Eppinger 2012) • **Technology feasibility risks** (Škec *et al*. 2014, Keizer *et al*. 2005, Unger & Eppinger 2009, Carbonell-Foulquie *et al*.2004, Luoma 2008, Cooper 2019) • **Environmental and safety regulations risks** (Mu *et al*.2009, Ulrich & Eppinger 2012, Hillson 2003, Aon 2017, Ricondo *et al*. 2006) • **Risk of lacking technical team competence** (Park 2010, Hillson 2003) • **Non-identification of technological gap** (Halman & Keizer 1994) • **Too narrow or wide design risks of product** (Škec *et al*. 2014) • **Risk of not involving market feedback into product design** (Cooper 2019, Unger & Eppinger 2009)
Market risks
• **Competitor risks** (Halman & Keizer 1994, Aon 2017, Cooper 2003, Hillson 2003, Park 2010) • **Risk on not identifying customer needs and value proposition for customers** (Halman & Keizer 1994, Hillson 2003, Cooper 2019, Škec *et al*. 2014, Luoma 2008, Kirkire *et al*. 2015) • **Changing market risks like economic, cultural & environmental (**Hillson 2003, Park 2010) • **Risk of not identifying target market** (Thäuser 2017, Luoma 2008) • **Missed "Value at market risk" calculation** (Chapman 2011)
Organisational risks
• **Team communication issues** (Hillson 2003, Thäuser 2017, Park 2010, Luoma 2008) • **Critical members leaving the project** (Park 2010) • **Organisational adaption to change** (Mu *et al*.2009) • **Inaccurate process and incomplete execution** (Škec *et al*. 2014)
Commercialisation risks
• **Financial resource capability risks** (Thäuser 2017) • **Product resource availability risks** (Ulrich & Eppinger 2012, Kinnunen *et al*.2011) • **Financial return on investment risks** (Ulrich & Eppinger 2012, Chapman 2011, IMA 2007, Cooper 2008) • **Capability to introduce and stabilize product in market risks** (Salavati *et al*. 2016) • **Development violating resource constraints, budget and time** (Cooper 2003, Thäuser 2017) • **Sales forecast and projections on the new product** (Thäuser 2017)

3 CURRENT STATE RM ANALYSIS IN CASE COMPANIES

This section explains the current state analysis based on the literature review findings by assessing the RM practices in PD companies. VCI perspective was also taken into considering in this study. This chapter primarily concentrates on assessing the RM frameworks utilised in the front end of the PDP/ESNPD, the RI techniques employed to identify risks at an ESNPD, and the common risks encountered by organisations at an ESNPD. This section aims to interpret the empirical results by identifying the key loopholes in the context of RM in the NPD process to provide necessary recommendations for the improvement of RM at an ESNPD. Section 3.1 explains in detail on how the empirical research process was conducted and the characteristics of the case companies interviewed in this thesis. The further sub-chapters lay out the current RM practices in all the 6 case companies with the final result synthesis on the empirical findings.

3.1 Empirical research process

The empirical research process shown in figure 12 begins with the literature review findings that played an important role in providing a foundation in the empirical research, especially in the preparation of the questionnaire which was designed as per the literature findings of the thesis. The semi-structured questionnaire (Appendix A) was designed aiming to find on what are the current RM process frameworks utilised in PD companies, the RI techniques utilised, and the potential risk identified at an ESNPD. Also, a separate questionnaire was utilised for VCI (Appendix B). Further, a short questionnaire of approximately 25 questions (Appendix C) was designed based on the various RI techniques investigated in the literature review and the common potential risks identified at an ESNPD from the literature review. The interviewees were asked to identify and tick the most commonly utilised RI technique in their company at an ESNPD process and parallelly state the method and the reason behind the utilisation of the ticked RI techniques. Further, the common potential risks section shown in Appendix C were categories in 4 risk categories with a multiple choice option of *"always considered", "sometimes considered"* and *"never considered"* choices, where "always and never considered choices" referred on the risks always or never considered at an ESNPD. On the other hand, the "Sometimes considered" choice was if the company considered the risk in a reactive manner rather than a proactive manner. This finding helped gain insights

on the risks faced by the case companies and also helped in understanding furthermore details on the risk consideration at an ESNPD.

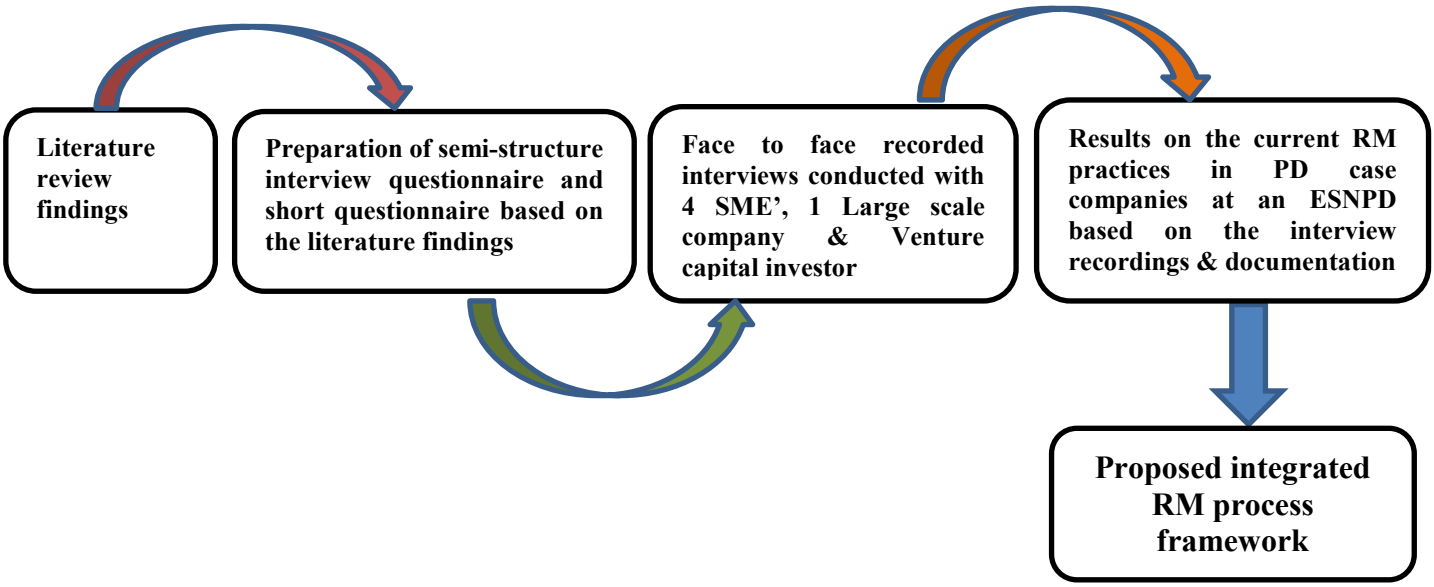

Figure 12. Empirical research process

Six face to face interview were conducted at 4 SME's, 1 large scale multinational PD company and 1 venture capital seed investor. The characteristics of the case companies interviewed are shown in table 8 below. The reason for selecting SME's and a large-scale company was to get a broad view on how RM operated at an ESNPD in different scaled company types. Seed VCI were considered for 2 main reasons, firstly to get a different perspective on how RM is conducted in PD companies as seed VCI invest with companies from a very early stage were most of the companies are in their developing stages and secondly to understand on what major risks are considered by VCI when investing in SME's as seed investors to get a perspective of risks from the VCI end. Hence the combination of the semi-structured interviews and the short questionnaire of 25 questions helped in gaining detailed insights on the overview of the current RM practices at an ESNPD.

Table 8. Characteristics of the case companies and VCI Company

Case Company's	Company Size	Product & Business Type	Duration	No of interviewees	Role of the Interviewees
A	Large scale global company	Tangible (B2B products)	1 hour	1	Product manager
B	SME	Intangible App development service products (B2B products)	1 hour	1	COO
C	SME	Intangible (B2B products)	1 hour	1	CEO
D	SME	Tangible (B2B products)	1 hour	1	CEO
E	SME	Tangible (B2B products)	1 hour	1	CTO
Venture capital investor					
Case company	**No of PD companies invested**	**Type of investor**	**Duration**	**No of interviewees**	**Role of the interviewees**
A1	54	Seed	1 hour	1	Main business partners

3.2 Current RM practices in case company A

Background information on case company A

Company A is a global telecommunication, information technology, and consumer electronics company with more than 150,000 employees. Company A has various business to consumer (B2C) and business to business(B2B) product businesses dealing with both tangible and intangible products. In this thesis, one particular business line is considered, where the product manager from the B2B tangible product type is interviewed. The products in this product family are globally operated and are dealing with continuous radical and incrementation innovation.

Managing risks at an ESNPD

Company A has a systematic set of criteria divided into sub-phases in the front-end process of NPD when it comes to the handling of risks at an ESNPD. These sub-phases mainly include the preliminary and detailed market assessment, technical assessment, and

financial assessment activities. These phases are conducted in a very explicit and systematic manner. Company A follows a milestone-driven approach in each subphase of the front-end process in the NPD process. Depending on the project type, the PDP are also tailored to different scalable product development models. For instance, incremental innovation of a similar product type in the product family does not follow all the sub-phase activities mentioned above.

The interview session with company A indicated that company A does not utilise an RM process framework integrated with the NPD process or neither a separate stand-alone external framework such as the ISO 31000, PMI OR PRINCE2 framework. Hence the criteria's set in each stage determines which risk should be mitigated/managed during the NPD process. However, there is no systematic RM procedure followed in managing risks in the front end of the NPD process. Risks are however, discussed in frequent review meetings held during these sub-phases within respective departments to full fill the respective needed criteria. Cross-functional review meetings of the development project are held at the start of the front-end process of NPD and at the end of the NPD process. Company A does not utilise any RM software or common platform to monitor risks at an ESNPD. However, the product manager mentioned that few departments employ their own kind of risk register or risk template to note down risks in the front-end process to ensure to meet the set criteria's. Company A calls the last stage of the ESNPD as the "product decision phase", where a cross-functional team decides on whether to take a "go" decision on the product or no. The main criteria's set in this phase is the in-depth market analysis, in-depth technical assessment and detailed financial analysis. The decisions made in this phase are purely based on the set criteria of company A and not through risk assessment procedures.

On the other hand, company A use to utilise a process called as a "risk end process" in the back end of the NPD process which involves the utilisation of a risk matrix tool to analyse the impact or severity of the identified risks in the development stages as per the product manager. Company A does not prefer having a separate risk department in managing risks but believes every employee in the company is responsible for the risk in their respective department.

Risks identified at an ESNPD

The organisation considered most of the technical, market and commercialisation risks at an early stage of NPD. However, organisational risk was observed to be neglected by company A, and the company considers it a substantial risk to be considered early in the process. In terms of incremental innovation, the organisation considers the past recorded risks as their main reference; however, when it comes to radical innovation the risks in each category increases and are aimed to be identified from scratch for company A. Table 11 shows the synthesis of risks that are "sometimes considered and never considered" by company A. From table 11 it can be observed that other than the organisational risk parameter company A has a good strong commercialisation, technical and market risk parameter. It is found through the empirical study that; organisational risks weren't considered as risks in the past in the NPD process. Company A finds the potential need of considering organisational risks as potential risks to be considered in the future especially when it comes to the risks on *"critical members on leaving the project"* and *"organisational adaption to changes".* These organisational risks can disrupt the NPD process as per the product manager.

Risk identification techniques to assess risks at an ESNPD

At "company A", RI is conducted differently for different product development projects. If the development is an incremental innovation process, the organisation utilises the risks identified in the past, usually by utilising the checklist analysis technique or historical data in general. However, for radical innovations, the company utilise a few RI techniques to identify the key risks the organisation is involved during the PDP. There is no specific technique company A utilises to identify risks, however, according to the short questionnaire conducted it is seen that the common RI technique used was brainstorming, checklist analysis, SWOT, expert judgement, assumption analysis, fault tree analysis, FMEA, QFD and root cause analysis. As mentioned above, every department utilises their own risk managing approach. Hence these tools can vary from department to department. Even in terms of the identification of the risks, there is an involvement of a cross-functional team only at the start of the process and at the end of the front-end process.

However, the utilisation of the techniques mentioned above depends on the phase of the PDP according to company A. Usually, in the starting phase and the end phases techniques like brainstorming, SWOT and expert judgement are used. For the sub-

processes like market study, technical feasibility study company A utilises techniques like FMEA, FTA, RCA and assumption analysis. The product manager does mention about the improvement in the RI techniques in the company and also finds a lack of in-depth knowledge on the utilisation of these techniques. Employees are also not given any training on the utilisation of these techniques.

3.3 Current RM practices in case company B

Background Information on company B

Company B is an app development company which provides B2B intangible product and service solutions. The company originates from Finland, Oulu and was established in 2015. The company currently consist of 20 employees. The primary field of business is providing visualisations solutions to residential real estate, commercial real estate and construction industries. The “floor plan product” under the product family of company B has captured a good market share in the market so far in comparison with their other product service offerings.

Managing risks at an ESNPD

Company B does not utilise a dedicated RM process in their NPD process. They believe in ensuring their product is ready for the market before the launch. Hence more amount of time is spent in the front-end process of NPD. Company B mentioned an approximate of 8 months was spent during the front-end process of NPD for one of their products in their product family. During this process, an in-depth market study was conducted to understand their target market very early in the process. The top-level management always ensures to challenge the technical and other departments in the company from the customer's point of view. One of the approaches followed by company B is to test their R&D team from a market point of view by identifying market risks through a set of checklist and FAQ’s made by the top-level management on the most anticipated flaws with the product. This checklist is designed by the chief operating officer (COO) and chief executive officer (CEO) with suggestions from other important top-level stakeholders of the company. This enables the company to identify and manage risk early in the process during the development of its prototype model for testing. Hence the market study and technical analysis go hand in hand in company B in terms of managing risks at

an ESNPD. This further enables the company to come out with a more refined product when launched into the market because of the continuous feedbacks as per the market requirements.

In terms of risk communication, the company is utilising a common platform like “Slack” to discuss matters related to risks which according to the organisation is the simplest and informal way to communicate in a single platform. However, major risk communication is usually done by the top-management in company B between the CEO and COO. The company believes in keeping RM informal because it helps not slowing down the front-end process and ensures the process to be less bureaucratic. The company does not utilise an RM process framework at the ESNPD. One of the reasons mentioned by company B is that they believe it is difficult to implement a structured process of RM into the NPD process because of their technology-driven solution and the organisation mainly focusses on releasing the product as early in the market. Hence time constraint becomes an issue if a structured RM is considered in their NPD process. Thus, the introduction of a dedicated RM process can slow down their agile PDP as per the COO.

Risks identified at an ESNPD

Most of the risks identified by company B during the NPD process at an early stage is market validation risks. Market risks are well emphasised in terms of the value proposition for the customers, customer requirements, target market etc. As per the COO, the major risks the company is currently facing are the “legal risks” and “product accuracy” risks. This risk occurs mainly because of the type of product the company is primarily involved in. These risks, according to the company, could be well planned before the development of the product. Hence the need to identify the necessary stakeholders involved in the project and the impacts due to the legitimacy stakeholders possess one of the most significant risks to deal with according to the COO.

Other than the risks mentioned above, company B lacks in considering organisational risks early in the NPD process. Most of the risks are well known to the organisation, but not always considered in detail by company B. As mentioned above, company B has a suitable methodology in involving customers early in the process by managing technical and market risks, however in terms of organisational and commercialisation risks it is only considered in a reactive manner. Company B feels organisational risks won’t have a huge impact in their current NPD process, but during the expansion of their product

portfolio, the company tends to feel these risks should be taken into consideration. On the other hand, after the short questionnaire, company B believes commercialisation risks can be considered proactively, especially by taking into account the financial return of investment, product resource availability and budget constraints early in the process. In terms of sales forecast, the company mentions that it is difficult to have a right forecast at an ESNPD, but also at the same time considers it as an essential aspect in the NPD process and even for their business processes. More details on the risks identified in company B can be found in table 11 in the synthesis section.

Risk identification techniques to assess risks at an ESNPD

The RI process is not precisely done in every phase of the NPD process in company B as the company's impression is that every risk cannot be considered during the PDP. However, there are pro-active techniques utilised by the organisation to identify and manage risks, as mentioned in the above sub-chapter. In terms of RI, the company mainly utilises techniques like SWOT analysis, checklist analysis and semi-structured interviews to identify risks during its business planning process and the NPD process. Risks are usually identified by the top management. However, one of the primary methods utilised is a checklist, where the COO and other top stakeholders prepare a checklist, and it is further discussed with the team on managing these risks better during the development process. The organisation mainly emphasises on market risks during their RI process, as mentioned in the above sub-chapter. Also, technical risks are mostly identified from the feedback of their customers, especially after the release of the beta version at an ESNPD. These risks are not explicitly addressed further in detail but are only identified to bring an awareness of the risk that needs to be considered during the PDP. The COO also believes the utilisation of more techniques can assist in the identification of the "sometimes considered or never considered" risks proactively, as shown in table 11.

3.4 Current RM practices in case company C

Background Information on company C

Company C is located in Oulu, Finland and consist of 8 employees. The business type of company C is providing B2B product solutions. The basic product platform of the company is providing internet of things (IOT) services which provide a direct solution

for knowledge management. The solution consists of 3 main innovative elements that are: firstly, the company C devices which collect measurement data in real time accurately, secondly the cloud service which ensures the data is stored securely and finally the end-user services which offer the end-users through an easy-to-use and intuitive user interface. Currently, company C is providing solutions for three main sectors that is the agricultural, food and construction sectors. The R&D and software development of the product is done in Oulu, whereas the manufacturing of the product is outsourced from Asia.

Managing risks at an ESNPD

Company A believes that at an ESNPD, it is the market risks that are very uncertain for the company, even though they are working in a B2B environment. Hence the primary most critical criteria for company C is to lower down the uncertainties in the market before entering into any sort of actual development. The first protocol step taken by company C is to provide a practical demonstration to their target market or customers. This is to ensure customer commitment at an ESNPD. Company C also follows an agile PD model with sprint iterative cycles to get validation from their stakeholders and identify new requirements from their stakeholders early in the process. Once the scope is researched upon, the prototypes are demonstrated and tested with the customers continuously with continuous feedback. Company C believes most of their market risks fall light on their shoulders through this approach of understanding the VoC continually into the NPD process at an early stage. Also, in terms of technical risks company C mainly focusses on the technical feasibility and again it is directly connected to the feedback received from the customers which make the market analysis and technical analysis for company C go hand in hand. In case there is a requirement for better accuracy in the product, the investments increase as well, which in turn increases the price of the product. Therefore, company C believes there is a need to strike a balance between the product performance and the price of the product, which is the most potential risk which needs to be balanced well early in the NPD process to avoid financial risks further down the NPD process. In other words, striking a balance between stake and uncertainty. One way the company is coping with financial risks is investing in many sectors. Hence that helps in balancing the financial risks as per the CEO.

Company C does not use a formal systematic RM process framework in the NPD process, but it is said to be embedded in an informal way everywhere in the process. The risks are

discussed with the team members, and there is cross-functional integration in terms of risk discussion. However, company C doesn't have proactive plans to manage future uncertainties, and one of the reasons the company doesn't believe in implementing RM as a dedicated process is because of the lack of time, budget and skills. Another primary reason for not having an RM process framework in the NPD process is because the company doesn't deal with many new products in its current portfolio, which doesn't show the reason of having an RM process framework in the company. The company feels the need for a structured RM process framework can be useful when there is more radical innovations or incremental innovations in the future.

Risks identified at an ESNPD

Company C mainly emphasises identifying market risk and eliminating market risks early in the process, as mentioned in the above sub-chapter. Company C identifies most of the major market risk at an ESNPD and considers it to be one of the most important as per the CEO. Major market risks like "not involving customers early in the process", "not identifying the right target market", "not identifying the customer needs and value proposition of the customer" and finally the competitors of the similar product in the market. From the technical risks point of view, the company conducts the feasibility study of the product especially in terms of the accuracy of the product, as the product demands efficient precision/accuracy and the company well identifies these risks. However other than the technical feasibility study, few risks under the dimensions of the technical feasibility were not always considered (sometimes considered) like "complexity of the technology, familiarity of the technology to the company, the strength of firms R&D, size of technological gap etc. Further details on the risks can be seen in table 11.

From the short questionnaire, it was retrieved that organisational and commercialisation risks are less taken into consideration in company C. However, company C feels that organisational risks do not impact the NPD process even if it's not considered at an ESNPD as the company consist of a limited number of employees. At the same time, from the short questionnaire, it was found that financial risks were the highest faced by company C at an ESNPD. Company C felt the potential need to consider commercialisation risks seriously early in the NPD process by planning the finances better in the front-end process of NPD.

Risk identification techniques to assess risks at an ESNPD

The RI process in company C isn't done formally. However, company C prefers utilising the traditional RI techniques like brainstorming, checklist analysis, SWOT and structured or semi-structured interviews to identify risks and in terms of technicality of the product, root cause analysis is commonly utilised in company C to identify risks in the product. Other techniques from the short questionnaire were familiar to the CEO, but due to the lack of resources and the need, it has never been utilised by the organisation to identify risks. Company C feels these techniques can be utilised when entering into a bigger market where uncertainties are unpredictable. Other than the above RI techniques, the company emphasised on expert judgement to be one of their most reliable RI technique to initiate the risk identification. Most of the risks that are identified by the company are also through expert judgements, and company C believes in taking risks to identify more risks.

3.5 Current RM practices in case company D

Background information of Company D

Company D develops advanced control systems for the steel and metal industries. Company D provides solutions that enable their customers to make real-time measurements directly from the high-temperature metallurgical processes, giving them quick and precise process control capabilities. The company consist of 5 employees and currently comprised of 2 tangible products for different purposes in one industry.

Managing risks at an ESNPD

The principal methodology utilised by company D to mitigate risks was the "trial and error" methodology. The core technological idea of the product had been in research for a long timescale of 5 years in company D, which strengthened the discovery and scoping stage in the NPD process. The underlying technology was already tested in the industry during the R&D phases, which brought in scope for the further development of the product in company D. The company does not have a step by step procedure in terms of PDP yet, however from the prior testing in the industry, it was clear for company D regarding the technological feasibility of the product in terms of technology at an ESNPD.

This methodology helped the company mitigate technological and few visible market risks early in the NPD process. Another reason company D considers the “trial and error” approach is because they believe their company is working in an ocean strategic platform, where such a product technology has never been introduced before. Hence the constant trial and error approach testing with the industry is necessary until the product is completely finalized.

Also, in terms of the target market, company D is clear on the target market and is currently focussing on only one industrial application. Company D does not have a separate RM process framework and manages risks in a very informal way. However, the company does find the need for a dedicated RM process because of budget, time and knowledge constraints. The company believes an RM framework will be necessary when the company expands globally and enters into different market segments.

Risks identified at an ESNPD

The main risks the company D has identified at an ESNPD is the technical and the market risks. In terms of financial risks, the company isn’t very much concerned about it at the movement as they believe their product is mainly dealing in a very uncertain environment and losing money is how they can finally come up with the right product. Also, from the short questionnaire, it was retrieved that technical risks and market risks were taken into account seriously at an early phase of NPD. However, in terms of organisational and commercialisation risks, these categories of risks were not much considered or identified by the company early in the process. Company D never considered most of the commercialisation risks at an ESNPD. Most of the commercialisation risks were a reactive process rather than a proactive process. Table 11 shows the risks that are sometimes considered (SC) and never considered (NC) at an ESNPD.

Risk identification techniques to assess risks at an ESNPD

Considering the RI techniques utilised in company D. From the managing of risks point of view in the previous section, it can be seen that company D has been continuously testing its product with the industry. The most common techniques that have been employed by company D is the brainstorming technique with a combination of expert judgement as per the managing director. However, in some of the cases, SWOT analysis is used by company D when approaching business Finland forums and investors. Also, in

terms of technical risk identification, the company finds RCA as an efficient tool to identify risks about the product. The above techniques are mainly used internally in the organisation. When it comes to techniques that are needed to study the external market, the most common RI techniques utilised are semi-structured interviews with the stakeholders by the utilisation of an informal risk questionnaire. Most of these techniques are being used in a very informal way in the organisation without any knowledge on the utilisation of these techniques.

3.6 Current RM practices in case company E

Background information of company E

Company E mainly deals with B2B tangible products and services. Their products are utilised in many industries like the steel industry, woodchips, bio-sludge, Chicken manure, waste sludge etc. The company consist of 6 employees and is located in Oulu, Finland.

Managing risks at an ESNPD

Company E follows an approach of continuously testing their prototype product in the industry to get the best results. Once the prototype is ready, the company ensures to involve the customers early in the process for better proof of concept by continuously testing it in the industries for better, more exceptional results of the product. In terms of the RM process framework, company E does not have an RM process framework in their NPD process. However, company E does follow a framework based on ISO 9000 and ISO 12000 standards, which mainly focuses on the technical risk point of view. Company E also utilises an RM template which consists of components like "*risk identified, machine director, standard type (ISO 12000 or ISO 9000), can the risk be seen, phase of risk, description of risk, scale of risk, task to reduce the risk and other risks to be solved under the identified risks".*

In terms of other risk categories related to the NPD process at an ESNPD, there is no proactive RM process framework utilised. However, risks are discussed informally and are usually addressed in weekly review meetings.

Risks identified at an ESNPD

Most of the risks identified in company E at an early stage are from the technical risk point of view, as mentioned in the previous sub-chapter. From the short questionnaire (Appendix C), it was found that company E lacks in considering commercialisation and organisational risks in their RI process. Technical risks are well considered in company E; however, from the short questionnaire (Appendix C), there were few technical risks which company E felt that it could be considered at an ESNPD. The technical risks are lacked to be considered in the design point of view as per the short questionnaire results from the CTO. In addition to which organisational and commercialisation risks were less considered at an ESNPD which was similar to most of the PD companies interviewed. On the other hand, the company finds the potential need to identify financial, organisational and commercial risks in the front-end process of NPD to ensure efficient development down the NPD process and after the product release phase. Table 11 shows the risks "sometimes considered and never considered" at an ESNPD.

Risk identification techniques to assess risks at an ESNPD

Company E mainly utilises RI techniques to identify risks pertaining to the product related risks, especially in terms of ISO 9000 and ISO 12000 standards. The common RI techniques to identify technical related risks in company E is the RCA, where these risks are inputted into a risk template as mentioned in the above section on how to further assess these risks related to the product from the technical risk point of view. On the other hand, RI techniques like "brainstorming, SWOT analysis and semi-structured interviews were the common RI techniques utilised to identify other related risks at an ESNPD.

Most of the RI techniques mentioned above were utilised in a very informal manner. There is no separate methodology or technique followed in terms of RI at an ESNPD to get a broad perspective of the risks. The company finds the need to utilise more RI techniques in a structured manner to identify potential risks at an ESNPD.

3.7 VCI analysis of company A1

Background information of company A1

Company A1 is a leading seed-stage venture capital (VC) firm, mainly focussing on the start-ups in Nordic countries. Company A1 gets involved with PD companies early on. Company A1 has invested in more than 54 PD companies with most of the product development companies having tangible products as their product types. 80% of the companies at the time of investment do not have any revenue. The company directly works with the founders and the team, and furthermore, full support is provided to the founders from all their partners as well. Hence, company A1 has a great track record in its business so far and understands the up's and down's in terms of risks various PD organisations face.

Risk identification techniques utilised for PD company's

In terms of the RI techniques point of view. The RI process plays a vital role in terms of taking investment decisions for company A1; however, it is very much connected to the criteria's set in the investment process altogether. To dig deep down the risks from the mentioned criteria's seen in table 9, company A1 utilises methods like brainstorming, SWOT analysis, assumption analysis, interview sessions and PESTLE analysis to identify risks. When the technology is out of the know-how for the venture, the organisation seeks the help of their experts like CTO to give inputs regarding the potential risks to be considered when investing in the product. Hence expert judgement is a useful RI technique for the VCI when it comes to technological advancement cases.

On the other hand, as per all the 54 companies, the venture has invested in, the venture hasn't noticed or observed on any PD that utilises risk identification techniques to identify risks in their NPD process. However, they are aware that their customers utilise informal methods to manage risks.

Potential risks that are taken into consideration

Investment decisions for VCI: The investment decisions for PD organisations as a seed investor is usually based on a set of criteria's set by the venture. The following criteria are not solely product development-based analysis but also analyses the business potential

of the organisation in a whole to make investment decisions. The criteria are mainly divided into three main categories that are "opportunity, investment and quality" and are shown in table 9 as follows.

Table 9. Three main criteria for an investment decision on PD organisations

Opportunity	Investment	Quality
Total addressable market	Required for proof of concept	Founder team
Ease of scalability or scale up	Required to product launch	Product and business model differentiation
	Required to validate business	Protection of market position
	Required to realise the opportunity	Current situation

From the criteria mentioned above's in table 9, the venture considers "The total addressable market" as one of the major investment decision criteria. This criterion mainly speaks about the "***how big is the market potential"*** and "***products relevance to the market"***. The second important criteria considered by the venture is the founder team, which mainly emphasises on "what is the capabilities of the team and willingness to develop the product and business?" And the third important criteria are the analysis of the product, business model differentiation and its competitive advantage. For the venture, market assessment is vital in which market validation plays an important role.

Potential common risks PD companies face

When considering the risks faced by PD organisations, the venture mainly looks into three risk categories that are the technical, organisational and market risk criteria. However, the financial risk criteria aren't considered by the venture, because that's the risk the venture is mainly dealing with and trying to mitigate for the PD organisation. Out of these three categories, the major risk as per the VCI and as stated by the interviewee was the *"risk of not involving the customer early in the process"*. This risk, according to their organisation, can cause potential problems to PD organisations down the process, and the organisation emphasises their clients to make sure customers are brought in early in the product development process. The company categorises risk for PD as technology risks, organisational risks and market risks. However, according to the short questionnaire (Appendix C), the following risks shown in table 10 were "sometimes considered" (SC)

or “never considered” (NC) as a criterion when investing in an organisation early in the process before development.

Table 10. Risks “sometimes considered” & “never considered” at an ESNPD in company A1

Technical risks	Market risks	Organisational risks	Commercialisation risks
Risks on environmental and safety regulations of the product being developed (SC)	External market risks like Economic, cultural and environmental (SC)	Communication risks within the organisation (NC)	Financial resource capability (SC)
Risks on the design of the product being too narrow or wide (SC)		Organisational adaption to changes (NC)	Product resource capability (SC)
		Risks on the inaccurate process and incomplete execution (SC)	PDP violating budget, resource ad time constraints

The framework utilised by the venture and in perspective to invested PD companies

In terms of taking investment decisions, a common framework assessment tool was used by company A1 is an excel spreadsheet. Mainly the risk identified were fed into an excel spreadsheet with the existing criteria’s as seen in table 9. Furthermore, these risks are analysed, and then methods are decided on how to proceed with the investment decisions. These risks are ranked by various participants using a scoring model in the excel spreadsheet.

When it comes to the experiences in the RM process frameworks utilised by PD organisations, the venture isn’t aware of any PD organisation utilising an RM process framework to manage and assess their risks as a dedicated process. Out of the 54 product development companies’ company A1 has invested in, none of the companies has provided them with a risk assessment procedure on their product. However, some companies have provided proof of concept and market research details on a fundamental level.

3.8 Synthesis on the current state analysis

This chapter provides the synthesis of the current RM practices in the PD industry based on the empirical findings. Table 11 provides a comparative description in a nutshell on the RM practices in terms of the management of risks, RI techniques and potential risks identified in terms of the always considered, sometimes considered and never considered risks at an ESNPD. Further synthesis on the challenges faced by PD organisations from the empirical study is laid out in this chapter.

3.8.1 RM process framework synthesis

In comparison to all the 4 SME's in term of RM at an ESNPD, it was found that company B and company C had a better RM approach in managing risks compared to company D and company E. However, in terms of risk documentation company E had some set of well-documented RM procedures for managing technical risks compared to other companies. Overall every SME had their own informal risk managing approaches, but none of them utilised a dedicated RM process framework integrated into their PDP nor a standalone RM process framework. Also, the PDP in company B and company C had a step to step NPD agile process, whereas company D and company E did not have any structured NPD process as such.

Company A, on the other hand, had a much well-structured PD model, which is designed in a criteria/milestone driven approach of managing risks. However, considering the involvement of RM in the front-end process of NPD, company, A was also found not to follow any formal RM process framework integrated with NPD nor a standalone RM process framework like ISO 31000, PMI etc. There was the absence of a common risk documentation platform in company A as well, but company A mentions the usage of an own risk documentation procedure in respective departments. Finally, when considering the perspective of VCI, it was found that none of the 54 PD companies they have invested has utilised a risk assessment procedure as per their knowledge or experience. To conclude, the common conclusion found from the conclusions was that none of the PD companies utilise an RM process framework or documentation procedure with no risk owner/ risk team involved in any of the interviewed companies.

3.8.2 RI techniques synthesis

From the empirical findings, it was evident that the most commonly used RI techniques in the PD industry, as shown in figure 13 were brainstorming, SWOT Analysis, structured and semi-structured interviews and root cause analysis. Expert judgement and root cause analysis were the second highest utilised identification tools. However, when investigating on the techniques utilised by large scale organisation, it was observed that company A utilised more RI techniques during their NPD processes like FTA, QFD, scenario analysis and assumption analysis in comparison with the SME's. From the interview sessions, it was observed that most of the SME's could not afford to utilise other sophisticated RI techniques because of the lack of resource availability, knowledge and skills on the utilisation of the RI Techniques. Another highlighted point that can be concluded on the RI techniques is that most of the companies utilised the RI techniques in a very informal methodology, especially SME's. At the same time, even company A did not utilise RI tools in a structured manner and mentioned that no training was provided on the utilisation of these techniques. Hence there is no much attention given in terms of RI methodology in case companies at an ESNPD in PD companies.

Further, most of the risks identified were at the basic level and not further identified in a detailed manner. One of the reasons why SME's consider SWOT, brainstorming and interviewing techniques as the most appropriate techniques is because it is the less costly and more time efficient.

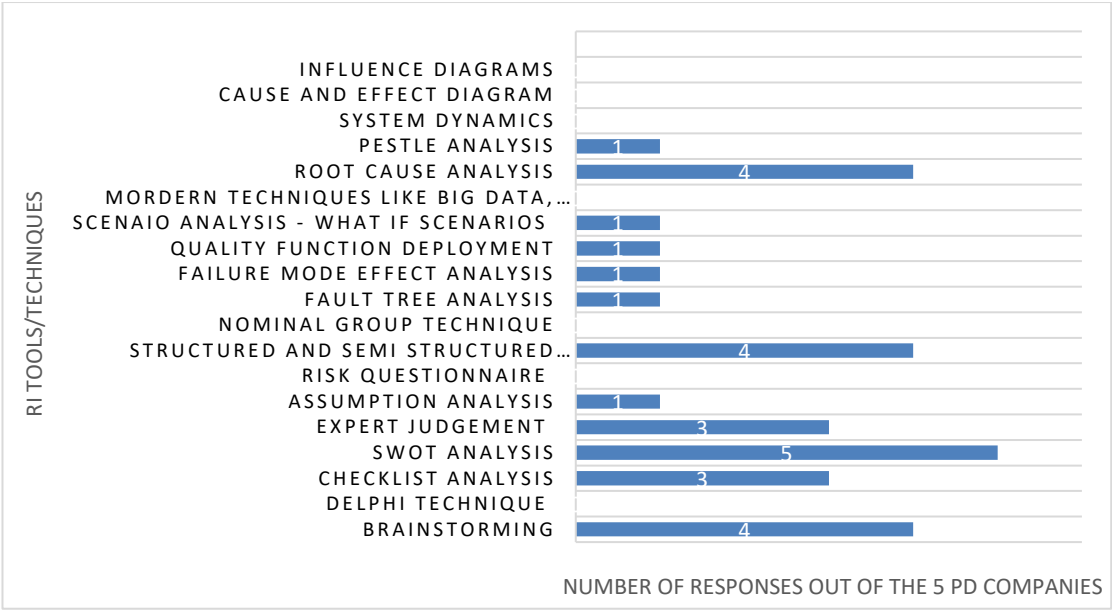

Figure 13. Synthesis of RI techniques utilised in PD case companies

3.8.3 Synthesis on the risks identified at an ESNPD

The following shows the synthesis on the risks identified at an ESNPD under all the risk categories from the short questionnaire (Appendix C) conducted in PD companies. It was observed that most of the SME companies focussed on technical and market risks, however, few companies find the potential need of considering few risks identified in the short questionnaire at an ESNPD even under the technical and market risk category. Organisational and commercialisation risks were found to be the least considered by most of the PD companies. Company A, for instance, found the potential need to consider organisational risks at an ESNPD. Most of the interviewed companies feel that a broad identification of risks early in the NPD process can improve the back-end process of managing risks efficiently. The common risks faced by the PD companies is shown in table 11.

Technical and market risks synthesis:

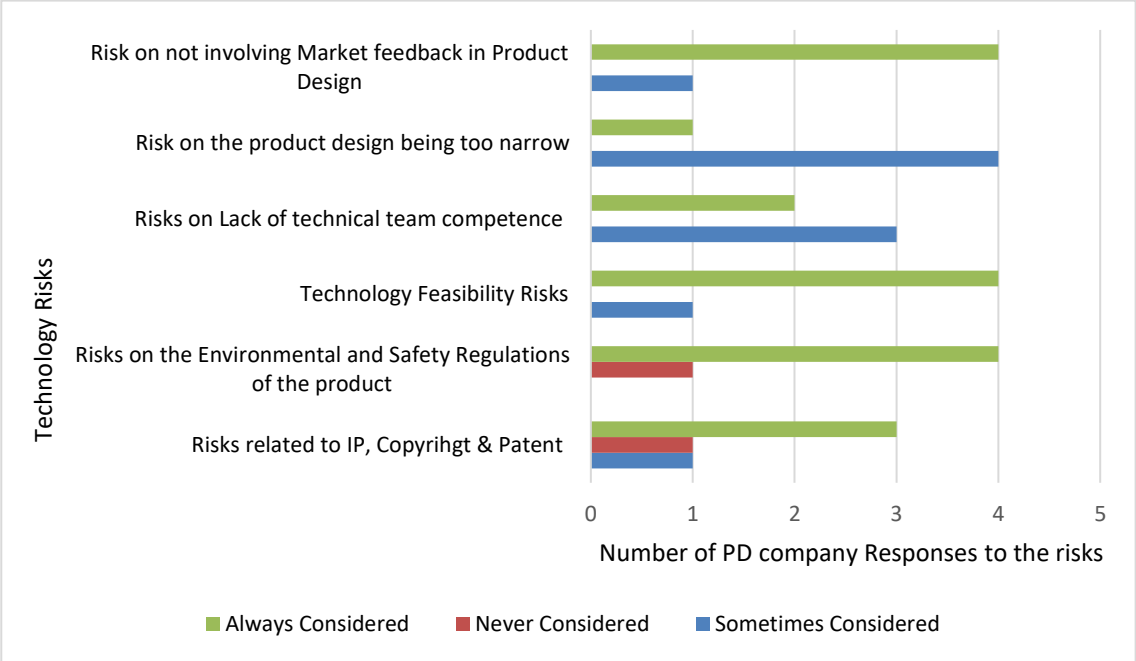

Figure 14. Synthesis of technical risks at an ESNPD in PD companies

Most of the PD companies emphasise on mitigating technical and market risks early in the NPD process. From the VCI perspective, technical risk, market risk and organisational risks are the most primarily considered in the investment decision-making process. VCI consider involving "customers early in the NPD process" as the most important activity

to be considered early in the NPD process to manage risks. The only market risks "not considered or sometimes considered" at an ESNPD by most of the PD companies is the external market risks like economic, social, environmental risks, political, and legislative risks. In the technical risk category, it is usually the risks related to product design and technical team competence. The synthesis of the technical and market risks from empirical research is shown in figure 14 and figure 15 as follows.

Figure 15. Synthesis of market risks at an ESNPD in PD companies.

Organisational and Commercialisation risks:

Based on empirical data, it was found that organisational risks were the least considered risk category at an ESNPD and second was the commercialisation risks category. Company A and company A1 consider this risk to be an important risk factor that can influence the NPD process. Company A mentioned on the potential importance of organisational risks at an ESNPD. From the interview sessions, it was observed that SME's rarely consider the organisational risks and commercialisation risks into consideration early in the NPD process. Commercialisation risks were not taken into vital consideration from the forecasting point of view at an ESNPD in SME's. The following figure 16 and figure 17 show the synthesis of organisational and commercialisation risk category in PD companies at an ESNPD.

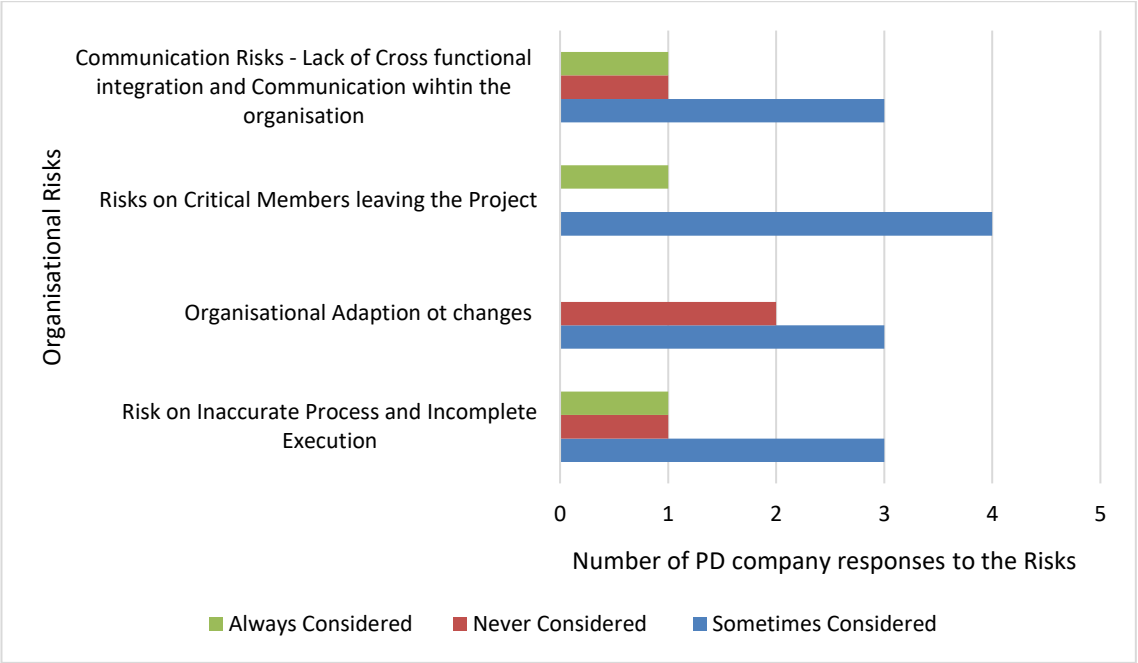

Figure 16. Synthesis of organisational risk at an ESNPD in PD companies

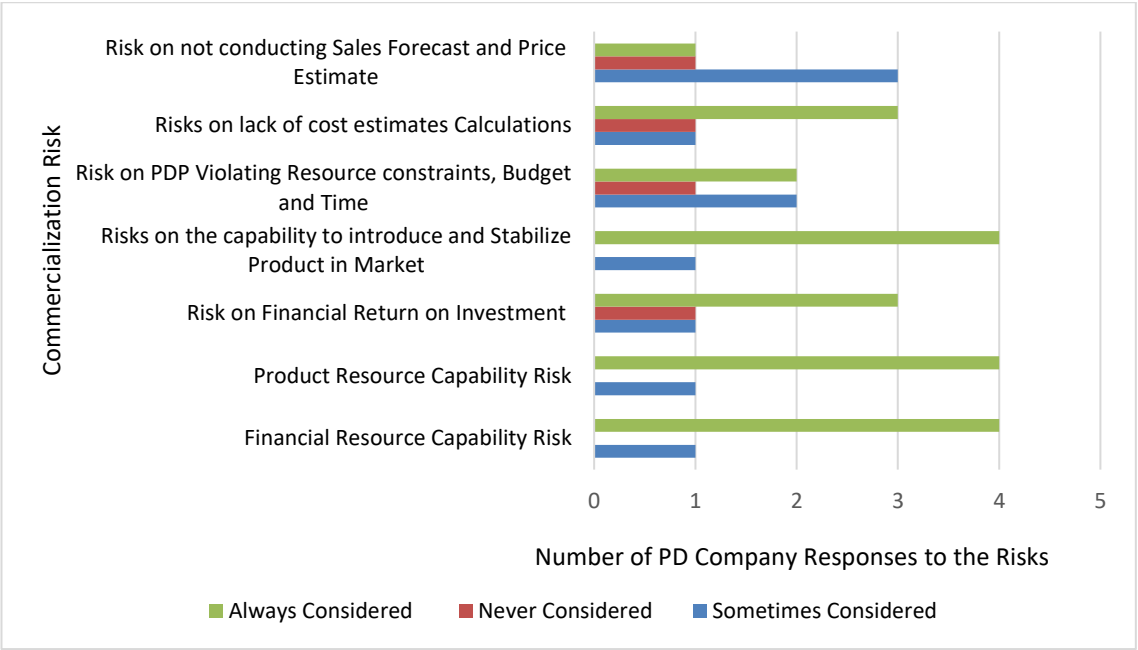

Figure 17. Synthesis on commercialisation risk at an ESNPD in PD companies

3.8.4 Synthesis of the common challenges faced by PD Companies

Most of the interviewed PD companies see a potential need for the implementation of RM as an integrated process at an ESNPD, but at the same time, most of the companies believe

there are many practical challenges to overcome. Hence the implementation of RM is seen as a generic challenge for companies. The following are the three main challenges in the implementation of RM in PD companies:

- Challenges in RM skills and knowledge
- Challenges in time constraints
- Challenges in budget availability at an ESNPD

Challenges in RM skills and knowledge

Most of the SME's consider it a challenge in providing training on RM, especially with the lack of resource availability for RM. On the other hand, company, A finds the potential need in implementing RM but believes there is a need for providing RM knowledge to most of the employees in the organisation to implement RM efficiently.

Challenges in budget availability

This challenge is mainly faced by SME's, where they have a limit in their budget requirements and find it challenging to invest in RM practices especially at an ESNPD, where the budgets are limited during the early phases of development. SME's at this stage cannot afford to have a resource allocated to RM in this stage.

Challenges in time constraints

As most of the SME's and large-scale companies utilise an agile NPD process. PD companies are mainly focussed on bringing the product in the market as early as possible. The agile PD model is designed in a way where the time is not a flexible option for PD companies at an ESNPD. Hence most of the SME's believe it is too much of non-value-added work in between their agile schedule. Some of the companies have a sprint iteration cycle of 2-3 weeks at an ESNPD, and SME's believe the implementation of RM in the NPD process can slow down their sprint cycle process.

Table 11 Empirical synthesis comparison between SME's, large-scale enterprise & VCI

SME			
Company B	**Company C**	**Company D**	**Company E**
RM frameworks			
*No formal risk management process framework in the NPD process.	* No formal risk management process framework in the NPD process.	* No formal risk management process in the NPD process.	*Formal RM framework used only in the technical risks point of view. No RM process framework used in terms of other relevant risks in NPD
*Market and technical risk quantification approach early in the NPD process by utilising checklist analysis methods and VoC approach.	* Market and technical risk quantification approach by utilising VoC approach early in the NPD process and feedback reviews	*Continuous testing with the target market – trial and error approach to quantify technical and market risks	*Continuous testing with the target market – trial and error approach to quantify technical and market risks
*Informal cross-functional communication in terms of risk discussion using "Slack" as a common platform. Major risks are discussed by the top-management and then discussed with the team	*Informal cross-functional team integration in terms of risk discussion	*No cross-functional team integration in terms of risk discussion	*Weekly review meetings held, where cross-functional teams discuss risk related matters
*Does not follow any external RM framework	* Does not follow any external RM framework	*Does not follow any external RM framework	*Does not follow any external RM framework. However, follows ISO 9000 and ISO 12000.
*Agile PD model	* Agile PD model.	*No systematic NPD process model utilised	*No systematic NPD process utilised
RI techniques			
*No separate RI structured technique utilised. Most of the techniques are utilised in an informal manner	* No separate RI structured technique utilised. Most of the techniques are utilised in an informal manner	* No separate RI structured technique utilised. Most of the techniques are utilised in an informal manner	* No separate RI structured technique utilised. Most of the techniques are utilised in an informal manner
*Main focus to identify technical risks and market risks early in the process	* Main focus is to identify technical and market risks early in the process.	*Main focus to identify technical and market risks	*RI techniques utilised mainly to identify technical risks due to ISO 9000 and ISO 12000 standards certification.
Main RI techniques used: *Checklist Analysis *SWOT Analysis *Structured and Semi-Structured Interviews *PESTLE Analysis	**Main RI techniques used:** *Brainstorming *Checklist Analysis *SWOT Analysis *Expert Judgement *Structured and Semi-Structured interviews *Root-Cause Analysis	**Main RI techniques used:** *Brainstorming *SWOT Analysis *Expert Judgement *Structured and Semi-Structured interviews *Root Cause Analysis	**Main RI Techniques used:** *Brainstorming *SWOT Analysis *Structured and Semi-Structured Interviews *Root Cause Analysis

Potential risks identified			
*The main risk considered at an ESNPD is the market Risk and technical risks. **Risks *"sometimes considered"* under the relevant risk category** *Technical risks* * Risks related to IP, copyright & patent issues of the product *Market risks* * External market risks like economic, cultural and environmental *Organisational risks* * Communication risks like – Cross-functional integration & Communication within the organisation * Risks on Critical members leaving the project * Organisational adaption to changes * Risks on the inaccurate process and Incomplete execution *Commercialisation risks* * Financial ROI *PDP violating resource constraints, budget and time *Risk of not conducting sales forecast and price estimates **Risks *"never considered"* under the relevant risk category** None	* The main risk considered at an ESNPD is the market Risk and technical risks. **Risks *"sometimes considered"* under the relevant risk category** *Technical risks* * Technical feasibility risks *Lacking technical team competence * Product design risks of being too narrow or wide *Market risks* *External market risks like economic, cultural and environmental factors *Organisational risks* * Communication Risks within the organisation *Risks on critical members leaving the project *Commercialisation risks* *Financial resource capability risks *Risks on the capability to introduce and stabilise product in the market *Risks of not conducting sales forecast and price estimates efficiently **Risks *"never considered"* under the relevant risk category** *Technical risks* * IP, Copyright & Patent issue risks *Organisational risks* * Risk on the organisation's adaption to changes * Risk of the inaccurate process and incomplete execution	* The main risk considered at an ESNPD is the market Risk and technical risks. **Risks *"sometimes considered"* under the relevant risk category** *Technical risks* *Risks on product design being too narrow or wide *Commercialisation risks* * Product resource capability risks **Risks *"never considered"* under the relevant risk category** *Market risks* *External market risks like economic, cultural and environmental *Organisational risks* *Communication risks *Organisational adaption to changes *Risks on the inaccurate process and incomplete execution *Commercialisation risks* * Product resource capability risks	* The main risk considered at an ESNPD is the market Risk and technical risks. **Risks *"sometimes considered"* under the relevant risk category** *Technical risks* *Technical team competence risks *Risk of product design is too narrow or wide *Risk of not involving market feedback into product design *Market risks* *External market Risks like economic, cultural and environmental *Organisational risks* * Communication Risks *Organisational Adaption to changes * Critical members leaving the project *Commercialisation risks* * Risks on the PDP violating resource constraints, budget and time * Risk of lack of cost estimate calculations *Risk of not conducting sales forecast and price estimates **Risks *"never considered"* under the relevant risk category** *Organisational risks* *Risks on the inaccurate process and incomplete execution

		* Risks on financial return on investment *Risks on the PDP violating resource constraints, budget and time *Risk of lack of cost estimate calculations *Risk of not conducting sales forecast and price estimates	
Most important risk company B is facing now that could have been considered at an ESNPD	**Most important risk company C is facing now that could have been considered at an ESNPD**	**Most important risk company D is facing now that could have been considered at an ESNPD**	**Most important risk company E is facing now that could have been considered at an ESNPD**
*As per the company Legal risks are currently an issue which could have been considered early in the process	*As per the company, Financial risks are the major risks faced down the NPD process, which can be considered or planned well early in the NPD process	*Financial risks could have been considered as per the company, but they consider as the part of the process of managing risks as well.	*Financial risks are something that can be emphasized as per the company at an early stage of NPD. *Also, commercialisation risks and organisational risks as per the company can be well managed early in the process to avoid estimate and communication issues.

Large scale enterprise

Company A

RM frameworks

*No RM framework used at the front end of the NPD process. However, a single platform risk assessment framework used in the back end of the NPD process

*The risks are assessed based on a standard set of criteria followed by a set of guidelines in the PDP.

*No separate risk teams. The product manager is the risk owner, and everyone in the organisation is responsible for their own risks.

*No utilisation of an external framework like ISO 31000, PMI, PRINCE2. Neither is the RM process designed from the above standards.

*No risk software or risk platform like a risk register utilised to monitor the risks.

RI techniques

*No structured RI procedures utilised. However, every department has its own RI processes to identify risks.

Main RI techniques used:

*Brainstorming *Expert Judgement

*Checklist analysis *Assumption analysis

*SWOT analysis *Fault tree analysis

*Quality function deployment *Scenario analysis – What if scenario analysis

*Root cause analysis

Potential risks identified

*Organisational risks seem to be the most neglected risk category in company A

*Few technology and market risks not considered, but these risks are considered based on whether the PDP is radical or incremental in innovation

Risks sometimes considered

Technical risks *Market risks*

* Risks of lacking team competence * External market risks like economic, cultural and environmental

Organisation risks

* Risks on the critical members leaving the project
* Organisational adaption to changes.

Most important risk company A is facing currently that could have been considered at an ESNPD

*As per the company, the organisational risk is the considerable risk that needs to be considered early in the process, which can avoid disruption in the process.

Venture capital investor perspective

Company A1

RM frameworks

*An own RM process framework is utilised. An excel tool template is used for RM in the invested PD companies.

*The risk assessment procedure consists of a set of criteria's the PD organisations should satisfy for company A1 to invest. The risk assessment decision is made through a scoring model in the excel template.

*Risk is communicated with all the stakeholders of the company.

*From the VCI perspective, no knowledge on any risk assessment procedure is utilised by any of the 54 PD companies the venture has invested in.

RI techniques

*No separate RI structured procedure followed

*RI techniques mainly used to identify risks in the product's perspective at an ESNPD.

RI techniques utilised to identify risks pertaining to the product to make investment decisions

*Brainstorming

*Checklist analysis

*SWOT analysis

*Expert Judgement

*Assumption analysis

*Risk Questionnaire

*PESTLE analysis

Potential risks identified

*The significant potential risk as per the VCI that should be considered by PD organisations at an ESNPD is the "VoC"

*The three main criteria's in terms of investment decisions on the PD companies are shown in table 9

4 INTEGRATED RM PROCESS FRAMEWORK

Based on the current state analysis, loopholes were identified in the RM practices by SME's and large-scale organisations in the process of managing risks in the empirical research. In addition to which RI techniques utilised by PD organisations were not utilised in a structured manner in all the 5 PD case companies with most of the companies utilising the least sophisticated RI techniques. The main loophole existed in the non-existence of an RM process framework. This chapter aims to provide necessary recommendations to provide a basis for the implementation of RM in SME's and large-scale enterprises. Recommendations from the VCI point of view were also considered in proposing this framework, which can help SME's. The framework shown in figure 18 utilises references from various RM external process frameworks, especially from ISO 31000 and other intrinsic frameworks relevant to NPD discussed in the literature review. The following figure 18 shows the proposed process framework for RM at an ESNPD.

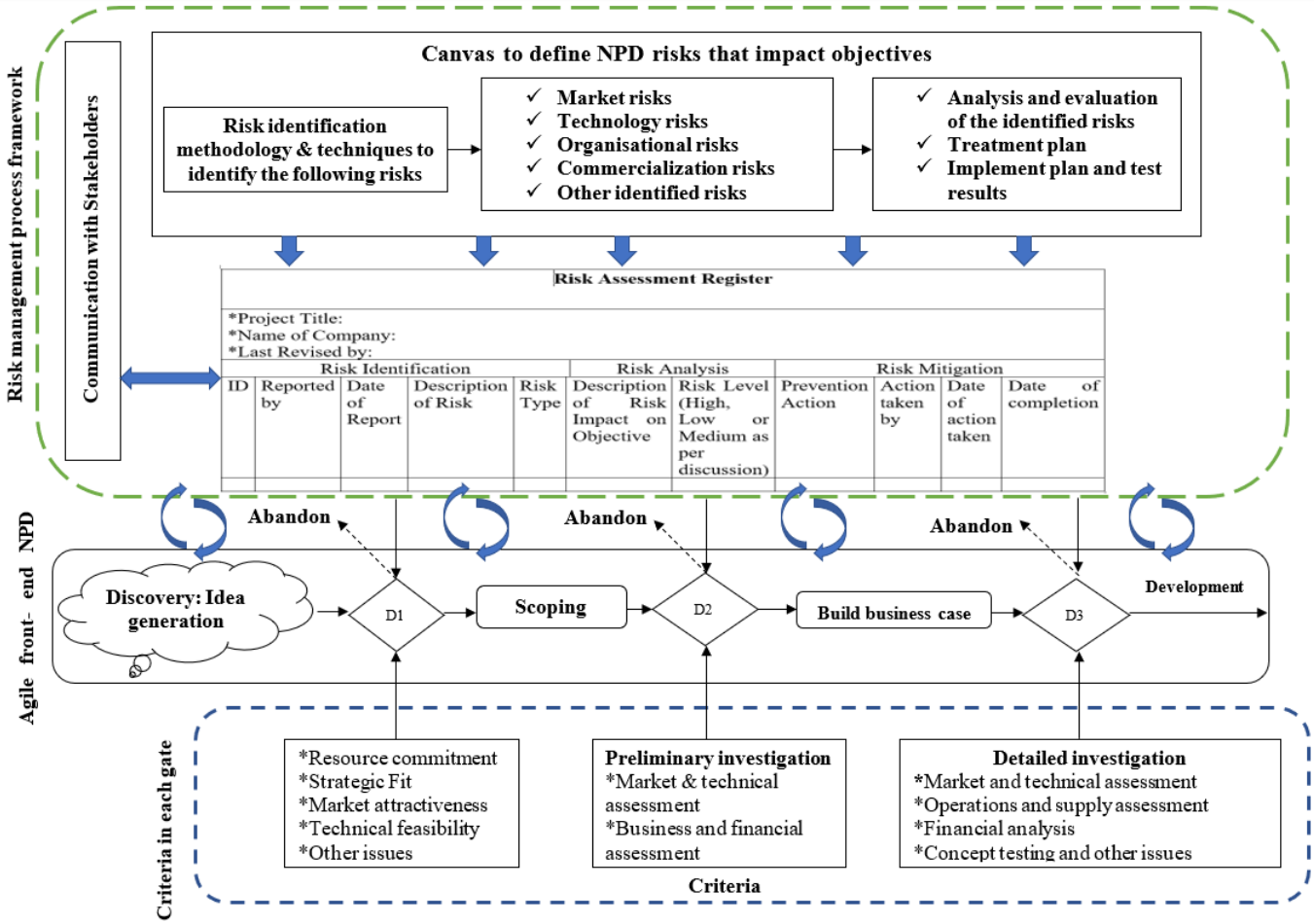

Figure 18. Integrated RM process framework

4.1 Need for an integrated RM process framework at an early stage of NPD

The need for such a proposed RM process framework is built considering the findings from the empirical research and challenges found in the PD industry, especially SME's. There were three main challenges found from the empirical findings on the implementation of RM as an integrated part of NPD. The first ranked challenge among all SME's and large-scale companies was the "lack of knowledge" in the utilisation of RM in the NPD process. The second and third challenges were time and budget constraints. Time constraints are another major issue as most of the PD companies follow an agile model and aim in bringing the product in the market as soon as possible. Especially the front-end process of NPD involves fast and short sprints with "on the fly" planning. The third challenge is one of the most common for especially SME's, which is the budget constraints, because of the limited amount of financial resources at an early stage of NPD. The finances are fixed and not flexible at an ESNPD.

Also, it was found that none of the organisations utilised an integrated RM process framework and a generic integrated RM process framework was also not recovered from the past literature at an ESNPD. The above-integrated model can help managers explicitly consider risks when making decisions in the NPD process, which can also help in terms of time constraints as this model is well integrated into the process and makes the front end of the NPD process efficient. Also, considering the lack of decision making at an ESNPD from the empirical research, this integrated RM process framework can aid in gaining valuable information pertinent to the project for better decision making. This model also helps in terms of the budget constraints for SME's as there is no requirement of any sophisticated techniques or software models. However, for large scale companies bringing in a common software platform can help making this model more efficient for large scale companies because of the amount of business processes involved.

From the results summary on the current risks faced by PD organisations, it can be found that organisational and commercialisation risks with few technical and market risks have been neglected in the NPD process. Due to the neglection of these risks, few PD companies face risk issues down the NPD process. Most of the small-scale companies work with radical innovations at the beginning stage of NPD with a lot of uncertainties involved. Hence this model ensures to take into consideration the four main categories of risk that can be considered in the NPD process.

Coming to the VCI point of view, it can be said that the VCI prefer start-ups to conduct their own risk assessment procedure, which can ease decision making for the VCI. It was also found VCI push their clients to utilise agile methodologies at an ESNPD. Even with some companies not having “proof of concept” at an early stage, this integrated RM process framework procedure can prove helpful for VCI’s to take appropriate decisions based on the company’s risk assessment as most of the VCI do a background study regarding the company in any case as found in the empirical research in company A1. There is a lot of uncertainties and ambiguity involved in the project in terms of the new market and technology the companies are dealing with these days. In addition to this, companies seek to be in a better edge than the other every day. This finds the common need for an integrated RM process framework model into the agile NPD process to ensure better adaptability and flexibility in the business process.

4.2 Integrated RM process framework at an early stage of NPD

This sub-chapter shows the process steps on the utilisation of the proposed integrated RM process framework for SME’s and large-scale enterprises. The most important part of this framework is the RI as RI plays an important role to ensure a broader view of risks is considered during the front-end of the NPD process. A RI methodology is also proposed in this framework, which is retrieved from the findings in the literature review and empirical research. The proposed process framework includes three main steps, as follows:

- Risk canvas.
- Continuous updating of risk assessment register.
- Decision at each milestone/stage based on risk assessment.

4.2.1 Risk canvas

This is similar to Corning's blank canvas approach as shown in chapter 2.5.3, where the team efficiently maps out the required action plan or proactive steps based on the information retrieved from the key uncertainties, unknowns and assumptions considered (Cooper 2017). However, the risk canvas in this process framework consists of mainly three steps: (1) RI methodology to create transparency regarding various risk categories in the NPD process. (2) Analysing and evaluating these risks and further identifying required information to validate the risks and unknowns (3) Key activities or action plan

to quantify the risks by receiving updated information vital for the next stage review. These three steps in the risk canvas ensure that every stage has its own custom-tailored plan, and this ensures that non-value-added activities are not performed during the process and makes the entire process less bureaucratic and much more flexible and adaptable. During this process, the risks are continuously updated to the risk register as well with continuous communication with the essential stakeholders.

From the steps mentioned above, the goal of this risk canvas is to identify a set of comprehensive lists of risks under the four categories of risks in the NPD process, keeping in mind the risks or uncertainties that will influence in achieving the objectives set by the organisation. The risk analysis gives a better understanding of the risks and their influence in the objectives on the causes of the risks to further quantify the risks. Furthermore, these risks are aimed to be evaluated on the risks that need to be considered to be treated. In SME's, it is suggested that these steps be integrated into the process due to the lack of budget, knowledge and time. Finally, a treatment plan is implemented to manage or mitigate these risks or uncertainties.

RI methodology:

RI is a vital step in the risk assessment process in the risk canvas. It involves the identification of risks and unknows based on the objectives/strategies set by the organisation. Considering the current state analysis in PD companies, it was found that most of the SME's use traditional RI techniques and large-scale enterprise use few sophisticated RI techniques, but all together none of the companies have a methodological structure on the utilisation of RI techniques. As such, 4 risk categories are considered in the NPD process as shown in the literature i.e., market risks, technical risks, commercialisation risks and organisational risks (Ricondo *et al*. 2006, Salavati *et al.* 2016, Mu *et al*. 2009) and the RI methodology aims in identifying risks under the 4 categories. *"Other visible risks"* other than the four categorised risks should also be considered if its necessarily impacting the objectives.

Before beginning the actual RI process, it is important to have a risk metalanguage to create transparency in identifying NPD risks. Risk metalanguage helps companies avoid the common mistake of identifying the cause of the risk or impact of the risks and confuse these with risks. Hence separating risks using a risk metalanguage helps in identifying actual risks by distinguishing them from their causes or effects. An excellent example of

a risk metalanguage that can be given as per the empirical findings and literature review is *"Our company is dealing with a completely new technology* ***(Fact = Cause),*** *hence we may not be able to identify what is our customer requirements* ***(Uncertainty = Risk)*** *and this would avoid our technological solution on meeting the objectives* ***(Contingent possibility = Effect on objective)****"* (Hillson 2009). The risk metalanguage concept with the utilisation of the three tenses of RI will help companies capture risks from three different time perspectives. The following table 12 shows an example of the suggested RI technique using Hillson's three tenses methodology by utilising three different RI techniques from different time perspectives.

Table 12. Example of tool utilisation using three tenses of RI

Risk identification techniques		
Past focussed RI techniques	**Present focussed RI techniques**	**Future-focused RI techniques**
Checklist Analysis	***Assumption Analysis***	***Brainstorming***
*Checklist can be utilised to capture a list of risks from past experiences or previous failures.	*Assumption analysis can view the present. This analysis can help in validating the assumptions made against the objectives or strategies set currently.	*This can be utilised as a future focussed technique on the risks that can occur down the NPD process.
*Checklist can be done individually.	*It can be done as a group or individually.	*Brainstorming is done as a group.
*Capturing past risks.	*Capturing present risks.	*Capturing risks that can occur in the future.

<u>Recommended factors for RI in the risk canvas:</u>

The following shows the recommended steps that can be utilised to identify risks in the NPD process in the risk canvas:

- To ensure the RI process is aligned to the objectives/strategies set by the organisation.
- To ensure the risk identified is explicitly addressed. Example: risk metalanguage.
- The RI process should be cross-functional and should take into consideration all human and cultural factors into account.

- The RI process should ensure to utilise more than one or more tool — for example: Hillson three tense methodology.

Analyzing, evaluation of the risks and necessary action plans:

In this step, risks are analysed and prioritized by ranking the most important risk to be taken into consideration. There are several risk analysis and evaluation tools that can be utilised in this stage like risk heat maps, tornado diagrams and decision trees etc. However, in SME's, this step may be integrated with the RI process to save time during the agile NPD process. Sophisticated analysis techniques can be considered by large scale organisations as there is no huge challenge in terms of budget. However, based on this analysis and evaluation, "action plans" are made on how to quantify or mitigate the risks based on the key risks and assumptions taken. Questions like "what information is vital to validate the key assumptions and risks" and "what activities are needed to be conducted to retrieve the information to manage risks", which is similarly asked in the Corning risk-based contingency model can be questioned to the team in this stage (Cooper 2017).

4.2.2 Risk assessment register

The risk register should be continuously updated during the risk assessment process. The documentation of these risks ensures that the risks are well monitored and reviewed by the entire team, which ensures control in the RM process. A well-updated register can help in taking quick, and clear decisions during the decision-making phase (D1, D2 & D3) as shown in figure 18. This can ensure RM to be a part of the decision-making process in NPD, as mentioned in one of the ISO 31000:2009 principles (ISO 31000:2009, p7). Furthermore, the risk assessment register can help in terms of future projects that can speed up the NPD process in the future.

4.2.3 Decision at each gate

One of the main requirements in the decision gate is the involvement of a risk owner. In terms of SME's, the top management like the CEO, COO, CTO can act as the risk owners who review, control and understand the risks throughout the process when it comes to taking the "go" decision in the front-end of the NPD process. On the other hand, large scale companies can invest their resources in the existence of a risk team with a risk owner

who controls, reviews the entire process. The decisions can be taken with the product manager in communication with the risk owner for large scale companies.

The decision on each gate is based on the risk assessment and the criteria's set in each stage. The risk assessment and the criteria's go hand in hand. However, the decision at this stage can more rely on the risk assessment as few of the standard set of criteria's may not be relevant for the particular project. Hence this makes the process more adaptable and flexible in terms of decision making. As Cooper (2017) mentioned, *"every project is unique and merits its own action plan"* (Cooper 2017). The decision gate (D1, D2, & D3) can be considered as a continuous information gathering process between the RM process framework and the NPD process. Finally, conclusions are made based on the risk assessment against the standard set of criteria's in each stage. The common standard set of criteria's is shown in chapter 2.0 for the front-end process for more details.

4.3 Mapping ISO 31000 process steps to proposed framework

From the literature review, it can be observed that most of the RM process steps relevant to PD are very similar to the ISO 31000 process framework. This chapter tries to lay the linkage between the ISO 31000 process steps to the proposed integrated model. The steps of *"communication and consultation"* and *"monitoring and review"* are considered as an organisational coordination activity within the RM process. Hence it is not considered in the mapping process. Figure 19 shows the mapping of ISO 31000 process steps to the proposed process framework steps. ISO 31000 has five main elements in the RM process. The "establish of context" can be directly linked to the objective setting, where the entire process follows the definition of ISO 31000:2009 on risks which define risks as *"effect of uncertainty on objectives"* (ISO Guide 73:2009, Definition 1.1). Hence the entire process is mainly conducted to avoid impact on the objective strategies of the organisation.

The rest four elements that are the RI, risk analysis, risk evaluation and risk treatment is integrated into one risk canvas where all of these activities are conducted. The proposed process framework has followed very similar process steps as the ISO 31000:2009 framework. This proposed framework is not only similar in terms of the process steps of ISO 31000:2009, but also in terms of the value principles followed by ISO 31000:2009. This integrated process framework emphasises on explicitly addressing risks, making

sure the process is dynamic, iterative and responsive for change, being a part of the decision-making process based on the best available information and also involving human and cultural factors into account. Most of the important principles of ISO 31000:2009 were aimed to be followed in the "integrated proposed RM process framework".

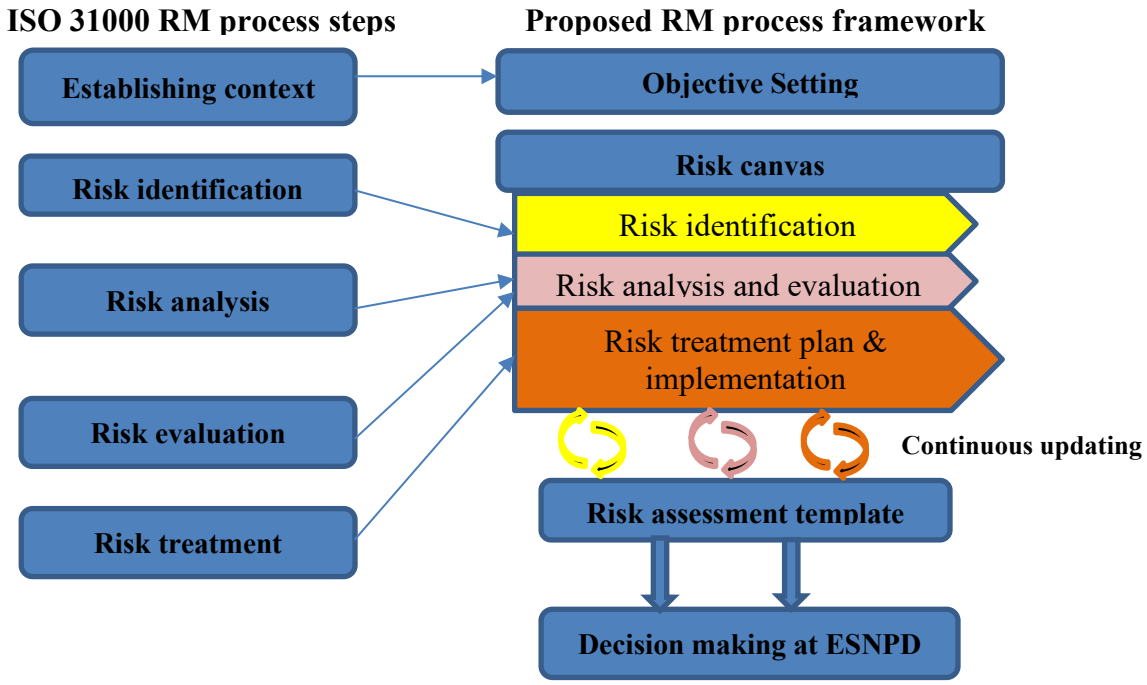

Figure 19. Mapping ISO 31000 process framework to proposed RM process framework

5 CONCLUSIONS

In this section, the results of this thesis are briefly discussed in the light of the goals, and related research questions (RQ) defined at the start of the thesis. Further, the contributions with the limitations and the future outlook of this thesis are discussed.

5.1 Research contribution

This thesis study addressed 5 holistic RM process frameworks related to the NPD process to get an understanding of how RM is involved in the NPD process. In this process, external frameworks like the ISO 31000, PMI and PRINCE2 provided a basis in understanding the 5 holistic RM process frameworks, where it can be observed that the 5 holistic RM process frameworks can be found to be similar to the external RM process frameworks, especially the ISO 31000 process framework. Hence a part of RQ1 is attempted to be answered by studying the various intrinsic RM process frameworks in the NPD process. Also, the external RM process frameworks gives scope for further recommendations to provide a basis for the implementation of RM in the NPD process.

The importance of RI, which is the part of the risk assessment procedure, was laid out in this thesis. Extending the literature research to further narrowing down the study to the various RI techniques available. RI techniques and methodologies were investigated to concretise the RI research domain. Since this thesis focusses on risks at an ESNPD, potential common risk identified at an ESNPD in the past literature were investigated and categories into the four important risk categories as per previous research. These identified risks were further aimed to be validated in the empirical research.

The findings from the literature review helped in addressing the RQ2 of this thesis. The current state analysis in PD companies found that most of the interviewees were familiar with the concept of RM in general and considered it to be an important role in the business process of the company. However, companies were not familiar with the concept of RM in the NPD process and also none of the companies had knowledge on the external RM frameworks like the ISO 31000, PMI and PRINCE2 frameworks. Companies considered RM as a bureaucratic process and PD companies prefer having it as an informal process especially for the following three reasons: (1) Lack of knowledge and skills in RM was considered as a significant challenge (2) As most of the companies follow an agile PD

model, “time” was recognized as one of the constraints in implementing RM. (3) Budget constraints was another critical issue for companies, especially when it comes to the initial phases of RM. Contribution in this section was mainly through semi-structured interviews and the short comprehensive questionnaire (Appendix C), which investigated in the current RM practices in 4 SME’s and 1 large scale enterprise located in Oulu, Finland. Also, VCI perspective was considered in this empirical study.

A common documentation platform of RM was found not to exist in any PD company. However, company E found to be documenting technical risk using an RM template, and some departments in company A utilised their own documentation process to manage risks in the front-end process. This points out the lack of control in the RM process as well, where risks are known, but not aimed to be planned for mitigation by most of the PD companies at an ESNPD. Coming to the RI techniques, it was found that only large-scale companies utilised few sophisticated techniques. However, there was no structured technique of utilisation at an ESNPD by any of the PD companies. Other SME’s revealed to be using the traditional RI techniques like brainstorming, SWOT, and checklist analysis frequently. It was however found that there is a lack of knowledge in the utilisation of the RI techniques in general in all 5 PD companies.

To understand the risks faced by PD companies at an ESNPD, the short questionnaire (Appendix C) found that technical and market risks are well emphasized on, however organisational and commercialisation risks were neglected at an ESNPD, which did cause problems for some SME’s and large-scale enterprise later down the NPD process and some of the SME’s faced common challenges in terms of budget prioritization at an ESNPD. There were three common conclusions that can be drawn from the empirical research (1) Firstly the most common challenge faced by all PD interviewed companies was the lack of knowledge in the integration of RM in the NPD process. (2) Secondly, the non-existence of RM in the NPD process was the common conclusion that can be drawn from the empirical research. No risk documentation and risk ownership were found in any of the PD companies. (3) No risk identification techniques were found to be utilised in a structured manner. Risks were identified at a basic level and not in detail. Further, most of the PD companies lacked in the knowledge on the utilisation of most of the RI techniques.

The findings from the literature review and the immersions in the empirical study go hand in hand in the proposal of an integrated RM process model at an ESNPD. Addressing RQ3, an RM process framework was proposed considering the overview on the loopholes and challenges faced by the PD companies. Point of view from VCI was also considered in the recommendation process. To improve RM practices in PD companies, this thesis proposes an *"integrated RM process framework"* to improve decision making at each stage in the front-end agile NPD process. This proposed framework applies RM methodologies from various external frameworks, especially the ISO 31000 and various intrinsic frameworks of NPD as well. The driving principle of this RM model is to ensure decisions in each phase is based on risk assessment through structured identification of the right risks pertinent to the project. However, the model emphasises in categorising risks in the four main risk categories found in the literature. This avoids non-value-added steps in the process, rather than following a bureaucratic model of considering a standard set of procedures. The categorisation of risks also ensures in the identification of a breadth of risks at an ESNPD. This RM process model can help strengthen the front-end process risks explicitly before investing in further development, which is a costly process. The proposed RM process framework can be used as a basis to provide more adaptability and flexibility in the NPD process.

5.2 Theoretical contribution

The fundamental literature contribution of this thesis is to provide the basic importance of RM at an ESNPD. Past literature has proved the impact of the 4 risk categories in the NPD performance (Salavati *et al.* 2016, Ricondo *et al*. 2006, Mu *et al.*2009) and also the importance of considering RM at an ESNPD (Cooper 2017). This thesis study complements risks identified by various authors in the NPD process (Škec *et al*. 2014, Keizer et al. 2005, Thäuser 2017, Hillson 2003, Luoma 2008, Ayala-Cruz 2016,Ulrich & Eppinger 2012, Unger & Eppinger 2009, Halman & Keizer 1994, Chapman 2011, IMA 2007) by synthesizing a list of risks under each category of risk that impacts the front-end of the NPD process. This set of risks are further utilised in the empirical research, and further help bring recommendations in this thesis. In addition to the external frameworks like ISO 31000, PMI & PRINCE2, various authors have also formulated different RM process frameworks for product design, innovation in the NPD process utilising these external frameworks (Park 2010, Bowers 2014, Cooper 2017, Levin & Kalal 2003, Oehmen & Seering 2011). However existing literature does not provide explicit research

on the current RM frameworks utilised in various PD industries and also doesn't attempt in giving a clear procedure on the techniques needed to support these RM process frameworks considering the challenges in the industry. Hence the literature review in this thesis fills this gap by synthesising various RM process frameworks relevant to NPD and further extends the literature review research in understanding the risk assessment procedures that can be used to support RM process frameworks in NPD.

Risk assessment is a broad field, and since RI is the most important step in the front-end process of NPD. It was observed that there is very limited literature found in the RI techniques in the context of NPD. Hence this thesis contributes to the RI techniques by laying out the available RI structured methodologies which can be utilised in the PD industry (Hillson 2009, Hillson 2002, Piney 2003) and various RI techniques (IMA 2007, Chapman 2011, ISO/IEC 31010:2009). In conclusion to the theoretical contribution, this thesis gives a good basis to the current literature available on how to integrate RM at an ESNPD and provides an excellent base knowledge on the importance of RM at an ESNPD with a variety of supporting RM process frameworks and RI techniques to in turn support the existing literature.

5.3 Managerial implications

This thesis proposes an RM process framework model that can help managers from SME's and large-scale companies to make their decision-making process more explicit rather than taking hasty quick decisions at an ESNPD, especially during the utilising an agile PD model. The model acts as an information gathering process which can remind managers on the changing risks in every phase of the NPD process and also to consider RM in the decision-making process. The concept of this model proposes managers to avoid the standard bureaucratic step of procedures which does not provide any value for the project, instead follow an RM process only for the pertinent risks for the current development project. Further, the risk template provided in the model can help managers to bring control during the RM process. The documentation in the risk register can be further used in the upcoming projects, which can speed future similar NPD projects. Managers from VCI find the need for companies to have a risk assessment procedure to ease their investment decision. This integrated RM process framework model can work as a win-win to both VCI managers and small-scale companies to ease the investment process.

5.4 Evaluation and limitations of the research

Even though the short questionnaire, semi-structured questionnaire approach and literature review illustrated an insightful understanding of the current RM practices in PD industries which helped in proposing an integrated RM process framework, some important drawbacks have to be considered in this study.

Considering the purpose of this study to integrate RM at an ESNPD, the sample size of large-scale companies was limited. This makes the results of this thesis more inclined towards SME's than large scale companies. The initial aim of selecting large scale companies was to enhance the findings in terms of RM process frameworks and techniques from large scale companies that could benefit SME's, but the results from the empirical research turned out differently than expected. In addition to this, most of the companies interviewed never understood the concept of RM as a formal process, but as an informal and a natural process. In this regard, most of the questions from the short questionnaire and the semi-structured questionnaire were only answered to a minor degree, and some of the questions were not explicitly answered.

Another major limitation that goes in connection with the above-mentioned limitation is the "time limit of the interview" and the "number of participants in the interview session". The time allocation and number of participants influenced the scope for further in-depth discussion. The results on the current state analysis on the case companies could have been more substantial if the time allocated bar was increased to 2 hours. Since risk management is a broad topic and is involved in all levels of management, ideally at least two personnel from the top and middle management could have been helpful to get in-depth details from different perspectives on the results in the current state analysis.

Some of the findings from the literature review may not align with the aim of integrating RM at an ESNPD. For instance, all the RM process frameworks relevant to the NPD process were not solely focussed at an ESNPD, but in terms of product design, innovation etc. In this context, the recommended RM process model needs to be further tested in the industry to validate whether it can be reliable for implementation. Another notable limitation in this study can be the broad research domain of RM. The recommended integrated RM process framework of this thesis has not considered risk analysis and risk evaluation techniques in detail, which makes the proposed framework incomplete in a

way. However, at the same time, it was practical to narrow down the risk assessment techniques to only risk identification, which helped in juicing out important valuable information on RI techniques and methodologies.

5.5 Future outlook of this thesis study

This section outlines the possible future research recommendations in this area of thesis study. This thesis can help open up several research domains which can be addressed for further investigation.

5.5.1 Risk management process framework in NPD

The proposed process framework can be empirically validated with SME's and large-scale companies in measuring the performance of the NPD process. The proposed process framework can be further enhanced by introducing a structured risk analysis, risk evaluation procedures or techniques, & risk management governance model prerequisites, which lacks in this thesis.

5.5.2 Risk assessment techniques

It was observed that most of the organisation have a very informal process with the utilisation of traditional RI techniques. Future research in this area can be the utilisation of the proposed RI methodologies in various case companies to measure the success of the proposed RI methodology. Furthermore, based on the success of RI, appropriate risk mitigation tools can be proposed that can be implemented in the PD industry.

On the other hand, this thesis lacks in providing in-depth information on the risk analysis and risk evaluation techniques at an ESNPD. Further research can be conducted on providing effective risk assessment techniques to support the current findings from this thesis.

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APPENDICES

Appendix A: Questionnaire model for PD case companies

Theme and questionnaire	Question number
Background information	
What type of products your organisation deals with? E.g., B2B OR B2C (Tangible or Intangible)	**Q1**
How many employees are present in your organisation?	**Q2**
A brief description of your title and roles in the organisation?	**Q3**
NPD Process at an ESNPD	
Could you describe the NPD process of your organisation until the pre-development stage or in other words till the product enters into actual development?	**Q4**
What are the common criteria or set of criteria considered to be ticked off before the product concept enters into the actual development of the product?	**Q5**
Risk management process frameworks	
Is your organisation implementing an RM process framework for new product development projects? If yes, could you give a detailed description of it?	**Q6**
Also, what ***"Risk management model"*** was relevant for the design of your tailor-made risk management process framework for NPD? Example of RM models are: *ISO 31000, PMI, PRINCE2 etc*	**Q7**
Risk monitoring	
Are all the risks identified entered into a risk register and further assessed or monitored? If yes, kindly could you explain the components of the risk register and give more details on this process?	**Q8**
Does your organisation use a platform to monitor risks? *For example RM software, excel techniques, by paperwork etc.*? If yes, a detailed description regarding it?	**Q9**
Risks identified at an ESNPD	
Could you kindly mention the common risks identified or considered at the early stage of NPD in the past other than the risks seen in the short questionnaire?	**Q10**
Could you mention some of the most critical risks that need to be considered early in the NPD process as per your experience?	**Q11**
RI techniques	
How does your organisation identify risks at an ESNPD?	**Q12**
What are the best RI techniques utilised according to your organisation?	**Q13**
Risk communication	
Are there cross-functional teams involved during the risk assessment process in NPD?	**Q14**
Are the risks identified communicated with various stakeholders for review?	**Q15**
How often are review meetings held for reviewing RM elements like identification, analysis, evaluation and mitigation in the NPD process?	**Q16**

Risk aware culture	
Are there qualified experts to help implement the RM process and give training regarding RM to the employees in the various organisation departments? (In other words, also a Risk Management team)	**Q17**
Risk management challenges	
What according to you are the challenges of implementing RM in the NPD process?	**Q18**

Appendix B: Questionnaire model for venture capital investors

Theme and Questionnaire	Question number
Background information	
How many product development companies have your venture invested in?	**Q1**
How many employees are present in your organisation?	**Q2**
A brief description of your title and role in the organisation?	**Q3**
Common criteria's and risks	
What are the common checklist criteria considered by your organisation before investing in PD organisations at an early stage?	**Q4**
What are the types of risks your organisation considers when investing in a PD organisation at an early phase of development?	**Q5**
Could you mention (as per your experience) the common list of risks PD organisations face down the product development process, which could be planned early in the process?	**Q6**
Risk management frameworks	
Kindly could you mention what are the RM frameworks your company utilises when investing in PD companies?	**Q7**
Also, could you explain in brief if you have the knowledge on the RM frameworks your clients utilise in their PD process?	**Q8**
Does any of your PD company clients follow the ISO 31000 risk management framework in their product development process?	**Q9**
Does any of your clients utilise RM software during their product development process?	**Q10**
RI techniques	
Kindly mention the RI techniques your organisation utilises in identifying risks in the PD companies invested in?	**Q11**
Also, kindly could you mention the common RI technique utilised by PD companies your organisation has invested in?	**Q12**
What seems to be the best RI techniques according to your organisation to identify risks in PD organisations?	**Q13**

Appendix C: Short questionnaire for case companies and venture capital investors

Risk Management Survey Questionnaire

This Questionnaire mainly consists of questions related to the Risk Management Identification Tools/Techniques utilized for Risk assessment to identify potential risks in the Product development process. In addition to which questions related to the common Risks identified at an Early stage of New Product Development (NPD) is also aimed to be studied through this questionnaire

1. **Kindly mention the name of your organisation**

_____

Risks Identification tools

The following Questionnaire are related to the risk identification tools utilized to identify risks at an early stage of New Product Development in your organisation.

2. **Kindly tick if the following Risk Identification tools are currently utilized in your organisation to Identify risks at an Early stage of New Product Development or in the Product development process? (Multiple options can be selected)**

Check all that apply.

- ☐ Brainstorming
- ☐ Delphi Technique
- ☐ Checklist Analysis
- ☐ SWOT Analysis
- ☐ Expert Judgement
- ☐ Assumption Analysis
- ☐ Risk Questionnaire
- ☐ Structured and Semi-Structured Interviews
- ☐ Nominal Group Technique
- ☐ Fault Tree Analysis
- ☐ Failure Mode Effect Analysis
- ☐ Quality Function Deployment
- ☐ Scenario Analysis - What If Scenario Analysis
- ☐ Mordern techniques like Data Mining, Big Data etc
- ☐ Root Cause Analysis
- ☐ PESTLE Analysis
- ☐ System Dynamics
- ☐ Cause and Effect Diagrams
- ☐ Influence Diagrams
- ☐ None of the above
- ☐ Other: _____

3. **Do you feel the Risks identified at an Early stage of NPD have been helpful down the New Product development process?**

Mark only one oval.

- ◯ Always
- ◯ Majority of the time
- ◯ Sometimes
- ◯ Never

Risk Identification at an Early Stage of NPD (Technology Risks)

The following Questionnaire are the common potential risks identified/Mapped at an early stage of New Product Development process from the past Literature findings in my Literature Review under the Technical Risk Category. Kindly mention if the following risks

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have been identified/Considered by your organisation at an early stage of Product Development.

4. **Risks related to Intellectual Property, Copyright & Patent issues of the Product**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

5. **Risks on the Environmental and Safety Regulations of the Product being Developed**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identfied at an Early Stage

6. **Technology Feasibility Risks - like (Risks regarding the Strength of the firms R&D, Engineering and Manufacturing unit skills, Usability of the Product, Size of the technical Gap, Complexity in the Technology, Familiarity with the technology to the company).**

Mark only one oval.

- ◯ Not considered/Identified at an Early Stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Idetified at an Early Stage

7. **Risks of lacking Technical Team competence?**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

8. **Risks on the products design being too narrow or wide?**
Mark only one oval.

- Not considered/Identified at an Early stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identified at an Early Stage

9. **Risk of not involving Market feedback into Product Design**
Mark only one oval.

- Not considered/Identified at an Early Stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identified at an Early Stage

Risks Identification at an Early Stage of NPD (Market Risks)

The following Questionnaire are the common potential risks identified/Mapped at an early stage of New Product Development process from the past Literature findings in my Literature Review under the Market Risk Category. Kindly mention if the following risks have been identified/Considered by your organisation at an early stage of Product Development.

10. **Competitor Risks**
Mark only one oval.

- Not considered/Identified at an Early stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identfied at an Early Stage

11. **Risk on not identifying Customer Needs and Value Proposition for Customers**
Mark only one oval.

- Not considered/Identfied at an Early stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identified at an Early Stage

12. **External Market risks like Economic, Cultural and Environmental**
Mark only one oval.

- Not considered/Identified at an Early stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identified at an Early Stage

13. **Risk of not identifying the Target Market**
Mark only one oval.

- Not considered/Identified at an Early stage
- Sometimes Considered/Identified at an Early Stage
- Always Considered/Identified at an Early Stage

Risks Identification at an Early Stage of NPD (Organisational Risks)

The following Questionnaire are the common potential risks identified/Mapped at an early stage of New Product Development process from the past Literature findings in my Literature Review under the Organisational Risk Category. Kindly mention if the following risks have been identified/Considered by your organisation at an early stage of Product Development.

14. **Communication Risks like- Lack of cross-functional integration & communication within the organization.**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

15. **Risks on Critical Members leaving the project**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

16. **Organisational adaption to changes**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

17. **Risks on Inaccurate process and Incomplete execution**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

Risks Identification at an Early Stage of NPD (Commercialization Risks)

The following Questionnaire are the common potential risks identified/Mapped at an early stage of New Product Development process from the past Literature findings in my Literature Review under the Commercialization Risk Category. Kindly mention if the following risks have been identified/Considered by your organisation at an early stage of Product Development.

18.

Financial Resource Capability Risk

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

19.

Product Resource Capability Risk

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

20.

Risk on Financial return on Investment

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

21.

Risks on the Capability to Introduce and Stabilize Product in Market

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

22. **Risk on the Product Development Process Violating Resource constraints, Budget and Time**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

23. **Risks on lack of cost estimates calculations - like Development costs, Support and Unit production costs, Marketing costs etc.**

Mark only one oval.

- ◯ Not considered/Identified at an Early Stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

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24. **Risk on not conducting Sales Forecast and Price Estimates (In order to manage and minimize the risk of product failure after the launch)**

Mark only one oval.

- ◯ Not considered/Identified at an Early stage
- ◯ Sometimes Considered/Identified at an Early Stage
- ◯ Always Considered/Identified at an Early Stage

25. **Any Comments?**